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AGRICULTURAL EXPERIMENT STATION

EAST LANSING

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THE QUARTERLY BULLETIN

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MICHIGAN STATE UNIVERSITY
AGRICULTURAL EXPERIMENT STATION
EAST LANSING

L. M. TURK, DIRECTOR
R. J. ALDRICH, ASSISTANT DIRECTOR
M. T. ALLEN, EDITOR

THE SANILAC PEA BEAN—ITS HISTORY, DEVELOPMENT AND CHARACTERISTICS

By AXEL L. ANDERSEN,[1] E. E. DOWN[2] and GERALD WHITFORD[3]

INTRODUCTION

Disease has played a major part in limiting bean production in Michigan. In the past 12 years several disease epidemics have occurred in Michigan causing extensive losses to bean growers. Bean anthracnose, caused by *Colletotrichum lindemuthianum* (Sacc. and Magn.) Bri. and Cav., was present in many fields in 1949, but did not cause extensive damage that year. However, the pathogen became so well established in 1949 that thousands of acres of pea beans were rendered unfit for market in 1950 and 1951 (1). The disease was especially destructive to beans in eastern Michigan from St. Clair county north into Sanilac and Huron counties.

Sclerotinia sclerotiorum (Lib.) Deby. causes extensive damage every year just prior to maturity. This pathogen causes sclerotinia wilt or white mold of beans. Common bean Mosaic (*Marmor phaseoli* Holmes) was observed in several fields near Saginaw in 1954 and by 1958 the disease reached epidemic proportions resulting in losses to Michigan bean growers estimated at $1,500,000. Similarly, common and fuscous bacterial blight caused by *Xanthonmas phaseoli* (E. F. Sm.) Dows. and *X. phaseoli var. fuscans* (Burk.) Starr & Burk., respectively, and root-rot, caused by *Fusariun solani* f. *phaseoli* (Burk.) Snyder & Hansen have taken their toll of Michigan beans during some seasons.

The disease resistance program initiated at Michigan State University in 1948 has as its goal the incorporation of resistance to the above mentioned diseases and the development of varieties with improved plant type and quality. In 1948, anthracnose appeared

[1]Senior pathologist, Crops Research Division, Agricultural Research Service, United States Department of Agriculture.
[2]Deceased. Formerly Professor, Farm Crops Department.
[3]Technician. Farm Crops Department.

ARTICLE 43–22

to be the most important of all the diseases and efforts were centered towards the introduction of resistance to this disease. The variety Sanilac was the first new bean to be released. It is resistant to all three races of *C. lindemuthianum;* is highly tolerant to *S. sclerotiorum;* and is resistant to the common bean mosaic virus race 1.

Although Sanilac has been compared to Michelite in earlier papers (5, 6), little information was included on the development of this variety and its relationship to previous bean breeding programs. Furthermore, additional research data and field observations are available on the Sanilac bean. This paper includes a résumé of the bean improvement program; a description of the materials and methods used in the research program; the results from the breeding program; a comparison of Sanilac and Michelite bean varieties, and the results from cultural studies that were made concurrently with the development of the Sanilac bean.

The bean improvement program is still in progress. Other varieties with different maturity dates, with additional disease resistance, with improved plant types, or with improved seed quality will be forthcoming. Similar, though less extensive programs, are in progress for improvement of red kidney, cranberry, and yellow-eye bean types.

REVIEW OF BEAN IMPROVEMENT IN MICHIGAN

In 1908 Professor Spragg selected a healthy pea bean plant from a lot of mosaic infected commercial beans. The seed originating from this plant was released in 1915 as the variety Robust (8). The variety was reselected and an improved strain was made available to seed growers in 1922. The Robust bean was superior to all other varieties grown in Michigan. According to Down and Thayer (7) 85 percent of the pea bean acreage of Michigan was planted to Robust during 1928-1938. The variety Robust lacked uniformity in seed shape and size and the seed coat frequently showed dark streaks and had a dull-greyish cast.

To obtain a bean with the disease resistance and growth characteristics of Robust, yet with a whiter seed coat and greater seed uniformity, several crosses were made between Robust and other Michigan varieties in 1925. Through a process of selection from the cross Early Prolific x Robust, a new variety was obtained and introduced in 1938 as Michelite (7).

In 1941, a small bean with a determinate growth habit (non-vining-or bush-type) was selected from a group of plants containing mutants produced by treating Michelite seed with X-ray (5). This bean was similar to but smaller and 12 days earlier than Michelite, the commercial vine-type bean from which the X-ray mutant arose. The Michelite bean was back-crossed to the mutant bean and several larger bush beans were obtained. These selections were later used as recurrent parents in the bean breeding program. Sanilac, the original X-ray mutant, and Michelite are shown in Figure 1.

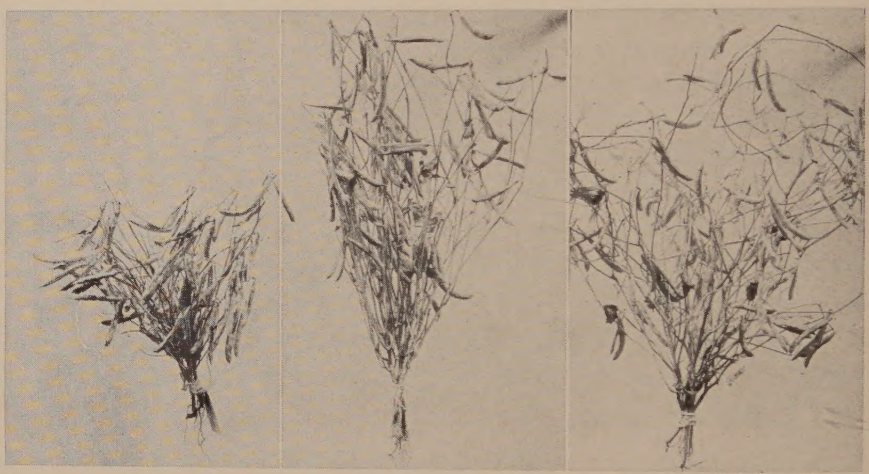

Fig. 1. Seed of the variety Michelite (right) was X-rayed and a bush mutant (left) was recovered that was 10 days earlier than the vine-type parent. The bush mutant was first crossed to Michelite and the selection crossed with an anthracnose resistant parent from which the anthracnose resistant variety, Sanilac (center) was selected.

MATERIALS AND METHODS

Breeding Program

Superior strains of pea beans were selected from stock bush- and vine-type material that had been tested in yield test plots in the Saginaw Valley and that had desirable plant types. Most of the vine types were selections from crosses made in 1925 involving Robust and other Michigan varieties. The bush selections were from a cross involving Michelite X-ray mutant bush (Figure 1) (5) back-crossed to Michelite three generations. Parentage, comparative yield, bloom, and maturity data are presented in Table 1 for the plant selections used as recurrent parents in the plant-breeding program.

TABLE 1—Selection number, plant type, parentage, yield (expressed as a percentage of Michelite), bloom, and maturity of the pea bean selections used as recurrent parents in the hybridization program

Variety or selection number	Plant type	Parentage	Yield			Days to					
						Bloom			Maturity		
			1948	1949	1950	1948	1949	1950	1948	1949	1950
Michelite	Vine	Robust x Early Prolific	100	100	100	47	49	45	88	95	94
50803	Vine	Robust x Early Prolific	126	92	—	40	45	—	89	80	—
50021	Vine	Robust x Crawford	136	100	—	41	45	—	86	93	—
53116	Vine	Robust x Mexican Tree	127	112	—	40	37	—	80	91	—
8374	Bush	Michelite X-ray x Mutant Michelite	—	118	88	—	39	39	—	84	88
8375	Bush	Michelite X-ray x Mutant Michelite	—	120	78	—	36	41	—	84	88
8479	Bush	Michelite X-ray x Mutant Michelite	—	106	94	—	37	39	—	84	88
8507	Bush	Michelite X-ray x Mutant Michelite	—	120	—	—	36	41	—	84	88

Michigan pea beans are resistant to the beta and gamma races of anthracnose. Therefore, only resistance to the alpha race of the organism need be introduced. Several sources of resistance were used initially but only a few appeared to be satisfactory for transferring immunity. Two of the strains were obtained from H. M. Munger, Cornell University, and were represented as Emerson No. 53 and No. 847. The first type was a green bush garden bean, whereas Emerson 847 was a large-seeded vine-type pea bean.

The breeding methods consisted of back-crossing to the recurrent parent for several generations followed by selfing for some four or five generations. Resistance was maintained by testing each generation in the greenhouse until true-breeding lines were established. Occasionally, segregating material was planted in the plant disease nursery at East Lansing for testing, but even though artificial inoculation was practiced the environmental conditions were not always favorable for the establishment of infection. Although infection could be established in the field plots, no secondary spread occurred. Greenhouse testing for disease resistance, therefore, was relied upon almost entirely.

Cultures of the alpha, beta and gamma races of the anthracnose organism were maintained on bean-pod agar. The conidia used for inoculation were produced on grain substrates which were seeded with conidia from 1-week-old bean pod agar cultures. The conidia were readily washed off the grain substrate and sprayed onto plants in the simple-leaf stage. The treated plants were incubated in a moist chamber at 68-72° C. for 48 hours (Figure 2). Anthracnose readings were made a week to 10 days later.

Plants tested under these conditions were highly resistant or if susceptible were killed by the fungus (Figure 3). Controls were always inoculated with conidial suspensions of each of the three races separately. The varieties Michelite, Dark Red Kidney, and Perry Marrow were used for differentials for identifying the anthracnose races (Table 2).

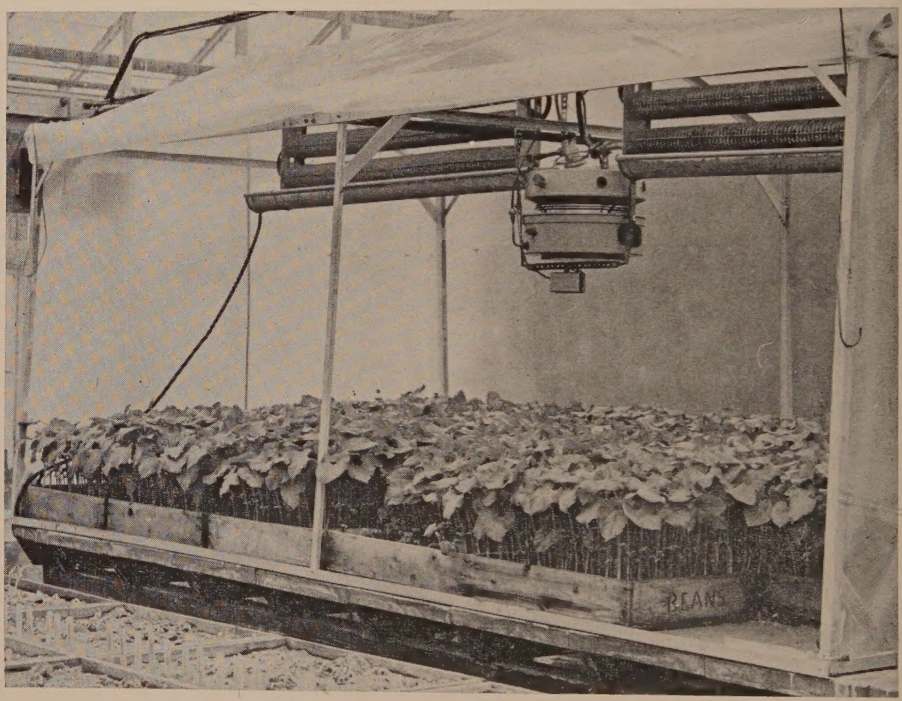

Fig. 2. Plastic covered infection chamber used in the disease resistance testing program. The humidity is maintained with a humidifier and is controlled by a thermostat. The air is cooled by a one-horse power refrigeration system that circulates refrigerant through a series of cooling coils suspended at the top of chamber. Bean seedlings from 400 single-plant selections can be tested for anthracnose resistance in two of these chambers at one time.

When homozygosity for disease resistance was obtained, the beans were planted in single-row plots in the Saginaw area for further single-plant selection work. When phenotypic uniformity was observed, the beans from a single-plant selection were composited and then tested in randomized yield test plots for another year or more. Final comparisons were made in replicated test plots and in

Fig. 3. Sanilac (left) and Michelite (right) 8 days after the 10-day-old seedlings were inoculated with the alpha strain of *Colletotrichum lindemuthianum*. Note resistance of the Sanilac variety.

overstate yield tests. Beans were also tested by researchers in New York, Ontario, Canada, and occasionally in Idaho.

Yield

The beans were pulled by hand and threshed in a machine originally designed by Brown and Thayer (3), but which had been completely modified to make it a mobile, self-contained unit which could be towed behind a car. Since only saleable beans were used to express yield it was necessary to deduct both screening and "pick" from the harvested sample. This was accomplished by taking

TABLE 2—Bean varieties used as differentials to identify the three races of Colletotrichum lindemuthianum and their reaction to them

Variety	Alpha	Beta	Gamma
Michelite.....	S	R	R
Dark Red Kidney....	R	S	S
Perry Marrow.....	R	R	S

R = resistant; S = susceptible.

200-gram samples from the field samples and passing these over and through a 19/64-inch round top screen and a 11/64 x 1/2-inch slotted bottom screen. Beans passing through the 11/64 x 1/2-inch slotted screen were considered non-commercial.

Intermediate sized round screens were used occasionally to determine the exact size of beans. The screened sample was hand-picked and the "pick" expressed on a percentage basis. The net yield was then expressed as a percentage of the control variety or in bushels per acre (bu./acre) of commercially acceptable beans.

Canning Tests

The original quality studies on the beans selected for use in the breeding program were made by researchers in the Department of Home Economics, Michigan State University. Later the food-processing laboratories of several commercial companies were made available for testing the canning quality of the bean selections. Recently the Food Science Laboratory at Michigan State University has assisted in the evaluation of the canned product.

Agronomic Studies

When the prospects for the development of an upright bush bean were considered, the question arose whether standard cultural practices for the production of the vine bean could be applied directly to bush beans. Beginning in 1949 and annually thereafter, experiments were conducted on the culture of bush-type pea beans. In 1949, several strains of bush beans and the variety Michelite were planted in 21-inch rows.

In 1950, both vine- and bush-type beans were planted in 24- and 28-inch rows. Neither of the plots which were set up in 1949 and 1950 could be analyzed statistically. In 1951, an experiment designed for the split-plot technique could be analyzed statistically. In this experiment two vine- and four bush-types were compared for yield in 24- and 28-inch rows.

The question whether early or late planting was advantageous for the production of bush beans resulted in establishment of an experiment in which both row width and date of planting were considered in 1955. The first planting, which included both 24- and 28-inch rows, was made on June 2 and the second on June 15. In this experiment the grower planted the beans by using a four-row

drill, and the experiment was set up on a Latin-square design. A total of 100 feet of each two center rows was harvested for yield. Similar experiments were conducted in 1956 and 1958 with 20-foot, three-row plots using a Latin-square design.

The effect of plant spacing (seeding rates) as well as row spacing was studied in an experiment in 1958. In this experiment 28-, 32-, and 36-inch row spacings with plant spacings of 2, 3, 4, and 6 inches were compared using two bush-type (Sanilac and Strain 3593 now named Seaway) and one vine-type bean (Michelite). The plant spacing was obtained by seeding heavily and thinning the plants to the desired spacing. The experiment was set up in a split-plot design with three-row plots 22 feet long. Twenty feet of each center row was harvested for yield comparisons.

EXPERIMENTAL RESULTS

Breeding Program

Considerable progress had been made by the beginning of 1952 in the anthracnose-resistance breeding program. At this time, 756 seeds were on hand from the fourth-generation back-crosses between Emerson 53 and 847 and the several pea-bean types. By the summer of 1952, four thousand 10-foot single-row plots, each representing seed from a single plant, were planted on the Alvin Nehmer farm, Saginaw, Michigan, and 500 additional plots were planted in the disease nursery at East Lansing.

Plants from approximately 1,300 plots were selected on the basis of seed shape and size and all the plants in each lot were composited for harvest and planted in the greenhouse for anthracnose resistance tests in the winter of 1952-53. From this group, 555 homozygous resistant lots of beans were saved and planted in 1953. Several were selected for possible introduction (Table 3).

Unlike 1952, 1953 was an excellent year for selection. Bacterial blight completely defoliated some of the beans and therefore, many strains were eliminated because of extreme susceptibility to bacterial blight. Root rot was sufficiently severe to defoliate prematurely several lines of beans in the plots.

This was also a year favorable for the development of sclerotinia wilt. Plant selections that matured late and had heavy vine growth, were especially susceptible to attack by *S. sclerotiorum*. The earlier, heavily vining types were also injured considerably. However, the

TABLE 3—Selection number, parentage, generation, and characteristics of six anthracnose-resistant pea bean selections made in 1953

Plant selection number	Parent	Source of resistance	Generation of cross	Days to bloom	Days to maturity	Plant type	Plant rating(*b*)	Seed rating(*b*)	Average yield (bu./acre)	Canning evaluation(*b*)
3737	50803	Emerson 847	F 4 BC5	34	78	Vine	5	5	38.5	Unsatisfactory
3742	50803	Emerson 847	F 4 BC5	43	83	Vine	5	5	34.7	No record
3867	53116	Emerson 847	F 5 BC5	34	76	Vine	5	3	31.8	Unsatisfactory
3889	Rainy River	Emerson 847	F 4 BC7	36	80	Vine	4	5	40.1	Unsatisfactory
3912	8479	Emerson 847 / Emerson 53	F 4 BC4	38	78	Bush	3	5	40.2	Unsatisfactory
3914(*a*)	8479	Emerson 847 / Emerson 53	F 4 BC4	41	83	Bush	5	4	39.5	Satisfactory
	Michelite			47	93	Vine	3	4	22.3	Satisfactory

(*a*) Sanilac.
(*b*) Rating Scale = 1 to 5; 1 is poor and 5 is excellent.
(*c*) Tests conducted by Stokely-Van Camp, Inc. and Campbell Soup Company.

upright bush types were for all practical purposes, completely free from the disease. The difference in the yield of Michelite (22.3 bu./acre) and Sanilac (39.5 bu./acre) resulted primarily from infection by S. *sclerotiorum*. The other bush and early vine beans also escaped injury from the disease.

One and one-half pounds of seed from each of the most promising appearing selections (3737, 3912, 3914) of the anthracnose-resistant group were increased in Florida during the winter of 1953-54. The seed harvested from the plants grown in Florida was increased at the University of Idaho Branch Experiment Station, Kimberly, Idaho, in the summer of 1954. In the meantime, samples were sent to canners for canning tests. Strains 3737 and 3912 were eliminated because they could not meet the quality standards of the processors (Table 3).

The 1954 trials in Saginaw were located on George Schemm's Cass River Farm south of Saginaw. The yields were low as compared with those for 1953. By the end of 1955, all small-plot information based upon observation and statistical data favored 3914 as the anthracnose-resistant selection to be introduced. Selection 3914 (Sanilac) is an F_4BC_2 from the 3-way cross [(50021 x Em 847) (8374)]X [BC_1F_1 (8479 x Em 53)]. (See Table 1 for parentage.)

Yield Studies

Yield tests have been conducted every year since 1948. It was not until 1953 that yield comparisons of Sanilac and Michelite were obtained. In 1954, the New York Agricultural Experiment Station began comparative tests which included the variety Monroe and other bean selections as well as Sanilac and Michelite. Finally in 1955, tests were arranged in the principal bean-growing counties with the cooperation of the Michigan State Extension Service and numerous bean growers.

The ability of Sanilac to produce as well or better than Michelite was clearly demonstrated in the experimental plots the year it was selected (Table 3) as well as in later years (Figure 4). Thus, in 1953 Sanilac produced 79 percent more marketable beans than Michelite; in 1955, 30 percent more; in 1956, 7 percent; and in 1958, 9 percent. No beans were harvested in 1957. Michelite outyielded Sanilac in 1954 by 7 percent and in 1959 by 16 percent.

The average yield from all the overstate yield tests the past five years was greater for Sanilac than Michelite. When all 49 trials over

the 5-year period are compared, Sanilac averaged 2.3 bushels more beans per acre, or 10 percent more marketable beans, than the variety Michelite. The yield difference varied from a low of approximately 1 percent (0.4 bu./acre) in 1957 to a high of 23 percent (4.5 bu./acre) in 1958.

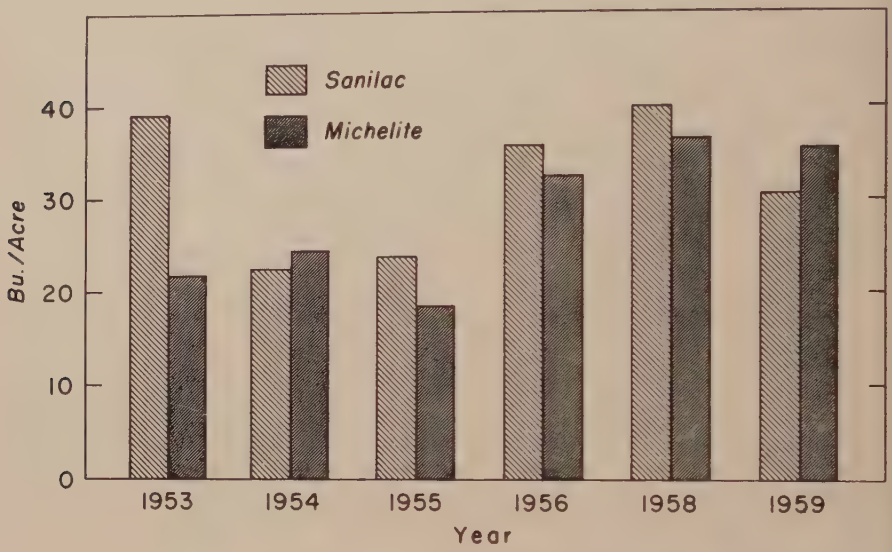

Fig. 4. Comparative yields of Sanilac and Michelite beans in experimental plots, Saginaw, Michigan, 1953-1959. Chart based upon average of 1 test each in 1953, 1954, and 1959, 2 in 1955 and 1956, and 6 in 1958.

When all tests were considered, Sanilac produced more beans on the average than Michelite in the nine principal bean-growing counties in Michigan (Figure 5).

In experiments conducted in 1959 to compare the regional adaptation of several varieties and strains of pea beans, Sanilac produced more marketable beans than Michelite in two of the three test locations in Michigan. At East Lansing, the Sanilac variety produced 7.5 bushels per acre more than Michelite; at Pigeon, 2 bushels more. At Saginaw, Michelite produced 4.9 bushels more than Sanilac.

The yield comparisons in New York do not show any significant differences between Sanilac and the two commercial varieties grown in that state (Table 4). There the variety Sanilac, on the basis of 8 tests conducted during 1954-1957, produced 28.3 bushels of marketable beans per acre as compared to 29.1 bushels per acre for the variety

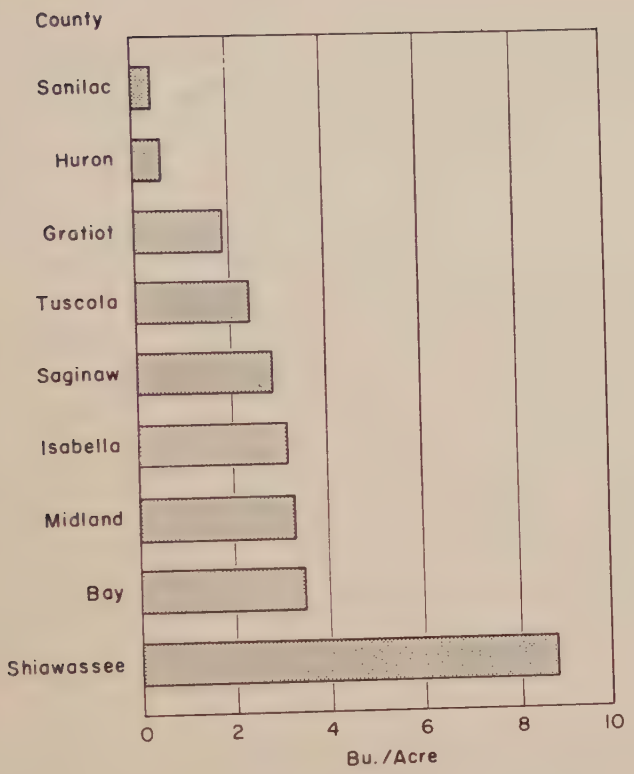

Fig. 5. Average increase in yield of Sanilac over Michelite beans in nine Michigan counties during 1955-1959. Results are based on 9 trials in Tuscola, 8 in Sanilac, 7 in Huron, 7 in Saginaw, 4 in Bay, 5 in Midland, 4 in Gratiot, 3 in Isabella, and 2 in Shiawassee County.

TABLE 4—Average yield and relative maturity of Sanilac, Michelite and Monroe varieties in New York from 1954-1957(a)

Variety	Yield (bu./acre)	Order of maturity
Sanilac	28.3	1
Michelite	29.1	3
Monroe	27.8	2

(a) Average value based upon 8 field tests.

Michelite. However, it is significant from the adaptability viewpoint that the variety yielded nearly the same as Michelite and Monroe in New York.

Variety Characteristics

Plant Type

The plants of Sanilac differ considerably from those of Michelite and other varieties of pea beans grown in Michigan. Sanilac has a determinate growth habit as compared with the indeterminate growth of the Michelite bean. Under average conditions, plants of Sanilac vary from 14 to 21 inches in height and produce a short determinate runner that may vary from a few to as many as 14 inches in length (Figure 6). As soon as the pods are set on this extended determinate runner, the added weight causes it to droop over into the row and become inconspicuous.

The pods, most of which are held well above ground level at maturity (Figure 7), vary in length from 3.0 to 3.4 inches. With good climatic conditions, the plants will set about five beans per pod. Bean seed counts for pods from numerous plants collected at random in

Fig. 6. Sanilac beans just prior to flowering. Note the determinate runner which extends above the plants.

Fig. 7. Close up of Sanilac beans in the row.

1959 varied from 2.8 to 5.0 seeds per pod per plant with an average for all plants of 4.3 seeds per pod.

Bloom

Blooming characteristics are important in the setting of seed and the development of a marketable crop of beans. Some of the important characteristics are time of bloom, ability to set a large number of blooms, period of bloom, location of bloom, and finally ability to reset flowers if the first set falls off the plant.

The number of days to bloom varies with the season. In 1953, Sanilac bloomed in 41 days after planting and Michelite in 47 days (Table 3). When the years 1953, 1954, and 1955 were compared, the average number of days to bloom was 47 for Sanilac and 53 for Michelite (5). The fact that Sanilac blooms approximately 6 days earlier than Michelite probably accounts for its earlier maturity. When Sanilac blooms, it produces an exceptionally large number of flowers over an extended period, a characteristic that favors the setting of a large number of pods.

In the location of bloom, Sanilac differs radically from the vine-

type varieties. In the vine-type the flowers are mostly set around the base of the stem and out on the vine and nonexposed. Sanilac flowers are set high on the plant and toward the end of the short determinate branches so that the pods which develop are generally up off the ground (Fig. 7). This is important in Michigan because of the considerable amount of ground damage and weathering that may occur to vine-type beans at maturity.

Seed

Sanilac seed is superior to Michelite in a number of ways. The seeds are more uniform in size and shape. For example, there will always be a few Michelite beans that do not pass through the 19/64-inch screen, whereas Sanilac seeds nearly always pass through this screen size (Table 5). Similarly, more Michelite beans pass through the 11/64-x ½-inch slotted screen. Field grown Sanilac beans have a whiter and smoother seed coat than those of Michelite, a characteristic that gives the bean a desirable appearance for the package trade. A comparison of the seed from the two varieties is made in Figure 8.

TABLE 5—Comparative bean seed sizes of Michelite and Sanilac grown in seven locations in Michigan in 1955 based upon the percentage of beans not passing through various screens of known dimension.(a)

Screen size (inches)	Sanilac (percent)	Michelite (percent)
On 20 round	0	0
On 19 round	0	1.0
On 18 round	2.7	6.5
On 17 round	11.8	17.4
On 16 round	38.4	31.2
On 11/64 x ½ inch slotted	44.4	41.5
Through 11/64 x ½ inch slotted	2.7	3.8
Pick	1.0	1.6

(a) The Sanilac beans were smaller than Michelite in 3 locations, larger in 2 locations, and the same in 2 locations.

Maturity

The maturity characteristics are probably most important to the bean producer. In eastern dry-bean areas, weather conditions are practically unpredictable. Beans pulled and windrowed may be

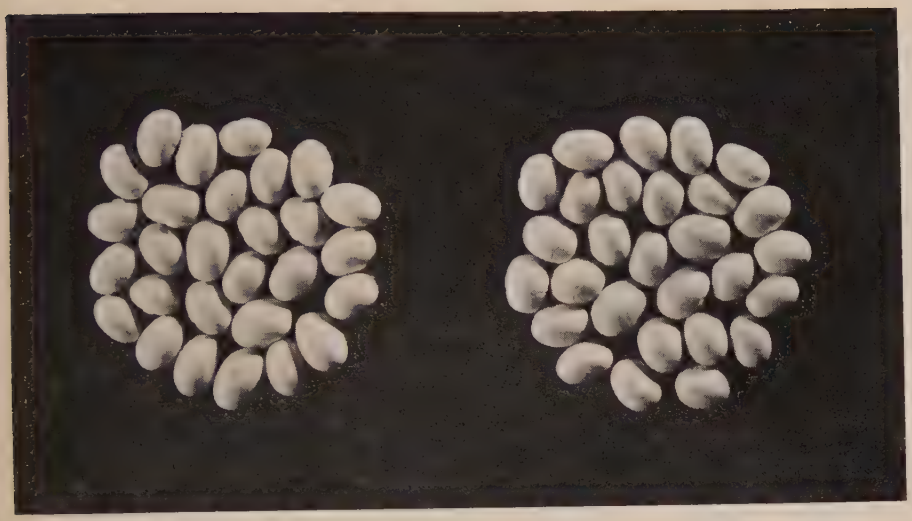

Fig. 8. Beans from field plots in 1959. Left—Sanilac; right—Michelite.

rained upon before they are dry enough for threshing. This may result in badly discolored and sometimes completely unmarketable beans. Hence, the importance of the two characteristics for maturity, uniformity of ripening and earlier maturity.

Sanilac beans mature uniformly. Because of uniform maturity the bean grower is able to leave the crop standing until the pods are fully ripe. By pulling and windrowing only the beans that the grower can combine in the afternoon of the same day, it is possible to avoid having beans in the windrow overnight. If it rains while beans are in the windrow, they may not be harvested for several days and are subject to damage from mildew and soil fungi.

Another characteristic that favors the Sanilac bean is its midseason earliness (Tables 3 and 4). Sanilac is earlier than Michelite. In 1953, this difference was 10 days, but under average conditions, the Sanilac variety matures at least 1 week earlier. Thus, Sanilac can be considered as an "88-day bean" (number of days from seeding to maturity) as compared with a "95-day bean" for Michelite.

Sanilac produces as many beans per acre as Michelite in a week to 10 days less time under favorable growing conditions. This lessens the risk to the bean grower by nearly 10 percent. The grower can produce his crop in a shorter period and thus avoid the extra days' exposure to disease, insects, weather, etc.

The earliness factor probably was responsible for several addi-

tional millions of dollars in farm income in Michigan in 1959. As a result of prolonged wet weather in the fall of 1959, 75,000 acres of beans (principally of the variety Michelite) were severely damaged.

Screening and "pick"

Data accumulated the past five years on screening and "pick" are summarized in Table 6. Screenings in this case refer to the beans that passed through a 11/64-x ½-inch slotted screen. The "pick" is made up of the culled beans in the sample after screening. These consist of beans discolored as a result of bacterial or fungal growths in or on the seed coat as well as by contact with water or the soil.

Results presented in Table 6 point out the advantages that Sanilac has over Michelite, namely that the "pick" and screenings are both considerably less for Sanilac than for Michelite. These data are based upon the results obtained from the 43 tests from the overstate trials conducted in the principal bean-growing counties of Michigan.

TABLE 6—Percentage of screening and "pick" for Michelite and Sanilac bean seed from the overstate trials, 1955-1959.

Variety and Year	Number of samples	Screening	Pick	Total	Variety and Year	Screening	Pick	Total
Michelite:					Sanilac:			
1955.....	7	3.8	3.3	7.1	1955....	2.7	1.4	4.1
1956.....	6	8.6	0.7	9.3	1956....	3.5	0.0	3.5
1957.....	7	...	...	5.3	1957....	...	...	4.3
1958.....	10	3.3	2.4	5.7	1958....	1.7	1.0	2.7
1959.....	13	8.8	7.0	15.8	1959....	5.2	2.4	7.6
Total or Average..	43	6.8	3.7	10.0	Total or Average	3.6	1.3	5.2

Canning Quality

Canning tests have been conducted every year since 1953. Sanilac has been satisfactory to the commercial canners, although it is slightly inferior to Michelite from this standpoint.

Disease Resistance

Disease resistance is of utmost importance in the development of improved varieties of beans. This feature alone will continue to play an important part in the acceptance of this variety. Thus in 1958, Sanilac was resistant to the virus responsible for the common bean

mosaic epidemic in the area around Saginaw Bay, Michigan. Again in 1959, Sanilac was not injured by *Sclerotinia sclerotiorum*, whereas many fields of Michelite were heavily infected. As was pointed out in earlier papers (5, 6) Sanilac is resistant or highly tolerant to numerous diseases to which other varieties of beans are extremely susceptible. The principal diseases and the comparative susceptibility of the Sanilac, Michelite, and Monroe bean varieties are shown in Table 7. These diseases are described in detail in other publications (2, 9, 10).

TABLE 7—Reactions of Sanilac, Michelite, and Monroe beans to several important diseases(a)

Disease	Sanilac	Michelite	Monroe
Anthracnose caused by alpha race	R	S	S
Common bean mosaic:			
Virus 1	R	R-S	R
Virus 15	S	S	R
Bacterial blight:			
Common	S	S	S
Fuscous	S	S	S
Sclerotinia wilt	Tolerant	S	S

(a) The three varieties are resistant to the beta and gamma races of the anthracnose pathogen. All other varieties of pea beans grown in Michigan are susceptible to all the diseases in this table.
R = resistant; S = susceptible.

Bean Anthracnose

Sanilac is resistant to the three races of *Colletotrichum lindemuthianum* known to be present in the United States. No effort was made to test for yield in the presence of *C. lindemuthianum* because during natural epiphytotics in Michigan fields of Michelite, Rainey River, and other varieties in which the disease was established have been made completely unharvestable by the fungus. The comparative reactions of Michelite and Sanilac to the alpha race of *C. lindemuthianum* is shown in Figure 3. No other pea bean varieties presently grown in Michigan are resistant to this disease.

Common Bean Mosaic

As shown in Table 7, common bean mosaic virus 1 and a variant strain of this virus (virus 15) are present in Michigan. A third strain, described by Dean and Wilson (4), was discovered in Idaho in 1954 in a field of Great Northern 123 beans. Sanilac bean is resistant to

bean mosaic virus 1, but is susceptible to the virus 15 strain and probably to the new Idaho strain. Michelite is only partially resistant to bean mosaic virus 1 and is susceptible to the other strains. The variety Monroe, developed in New York State several years ago, is resistant to both bean mosaic virus 1 and virus 15. Its reaction to the Idaho strain of the virus is not known. All other varieties grown in Michigan at present are susceptible to all three of the bean virus strains.

Bacterial blight

Sanilac is resistant to halo blight caused by *Pseudomonas phaseolicola* (Burk.) Dows. but moderately susceptible to common and fuscous bacterial blights caused by *Xanthomonas phaseoli* and *X. phaseoli* var. *fuscans*, respectively. Since these two diseases cannot be distinguished by field symptoms, the two are considered by growers as one disease. Because of susceptibility to the two bacterial pathogens, it is important that growers plant seed free from bacterial blight.

Sclerotinia wilt, or white mold

Sanilac normally escapes infection by *Sclerotinia sclerotiorum* because of its habit of growth. Only under conditions of extremely luxurious vine growth together with favorable environmental conditions has this variety succumbed to the ravages of the disease. In Table 8 are given comparisons in yield of Michelite and Sanilac in which sclerotinia wilt was principally responsible for the differences in yield.

TABLE 8—Location by county, year and the comparative yield in bu./acre of Michelite and Sanilac in experimental plots and overstate trials in which the beans were infected by Sclerotinia sclerotiorum

Variety	Saginaw 1953	Huron 1953	Tuscola 1956	Midland 1956	Shiawassee	
					1958	1959
Sanilac	39.4	37.5	31.5	29.3	38.4	25.0
Michelite	22.0	27.1	23.8	14.2	31.4	14.2

Introduction and Reselection of Sanilac

Seed from 20 acres of strain 3914 grown by the Michigan Foundation Seed Association in Michigan in 1955 was officially released to the Foundation Seed Association as the variety Sanilac in 1956. In that

year 150 acres of Sanilac were planted for Foundation Seed in Michigan. In 1957, the Michigan Crop Improvement Association certified 32,515 bags of the variety for planting in 1958. In 1958, 36,000 bags were certified for planting in 1959. Last year, 3,700 acres were certified, making 42,400 bags of beans available for planting in 1960.

In 1956, Sanilac was reselected and retested for anthracnose resistance. Seed was increased at Twin Falls, Idaho, in 1957, and in 1958, sufficient breeder seed was turned over to the Foundation Seed Association to plant 10 acres of seed in Idaho. Some of this was grown as certified seed in Michigan in 1959 and will gradually replace the present stock of Sanilac.

Cultural Studies

It appeared that a bush pea bean was a distinct possibility for Michigan agriculture when they were grown and observed in the field plots in 1948 and 1949.

Such a bean would be considerably different from the present vine bean; so experiments were begun to assemble data on cultural methods for the production of bush beans. Three phases were investigated during the 1949-1958 period. Initially, studies were conducted on width of row. Later studies were added on date of planting and finally, in 1958, the investigations included plant spacings and row widths.

The results during 1950-1956 indicate that a 24-inch row spacing may occasionally improve yields, but the extra crowding probably results in greater losses from diseases, especially sclerotinia wilt. The crowding of the plants would also favor the development and spread of bacterial blight, a disease for which we have no satisfactory resistance.

Since no benefits were gained by decreasing the normal row width, the question which remained to be answered was whether a wider row width could be used without sacrificing yield. In 1958, a five-replicate experiment was designed to compare the yields of three varieties, Michelite (vine), Sanilac, and strain 3593 (bush) in 28-, 32-, and 36-inch rows with plant spacings of 2, 3, 4, and 6 inches at each row width for each variety (Table 9).

An analysis of the experimental data indicated that only for Sanilac was there a significant difference between row spacings. There were highly significant differences between the 6- and 4-inch and between the 6- and 2-inch but not between the 4- and 2-inch seed spacings of

TABLE 9—The comparative yield in bushels per acre of Sanilac, Michelite, and 3593 when the plants were spaced at 2-, 4-, and 6-inch intervals in rows 28, 32, and 36 inches apart

Variety	Seed spacing—inches			Row spacing—inches		
	2	4	6	28	32	36
Sanilac.....	41.5**	39.8**	36.2	41.2*	38.6	37.7
Michelite.....	39.3*	38.9	37.2	39.5	37.9	37.9
3593.....	38.5	38.0	37.1	38.4	38.6	37.2
LSD.....	2.6 at 1 percent level 2.0 at 5 percent level			2.4 at 1 percent level 1.8 at 5 percent level		

*indicates significance at 5 per cent level.
**indicates significance at 1 percent level.

Sanilac. Michelite and 3593 showed little differences between seed spacings. An analysis of variance of the entire experiment showed that there was no interaction between row spacing and variety, between row spacing and seed spacing, and between seed spacing and variety.

Environmental conditions play a very important part in the total yield of beans. Comparisons in experimental plots made the past several years have always favored earlier (about June 1-5) planting over planting from June 10-16. A brief resume of the environmental conditions during the past several years will indicate the importance of these conditions as far as date of planting is concerned.

In 1955 dry weather reduced the yields of the later maturing varieties much more than those of early-maturing ones. For example, Michelite, a late-maturing variety yielded 23.8 bushels per acre when planted June 3 as compared with 14.6 bushels per acre for the June 16 planting. Selection 3443, an early-maturing type yielded 24.2 and 23.0 bushels per acre, respectively, when planted on the same dates. In 1956, the later planting was discarded because of drought. The 1958 experiments were conducted under ideal conditions of temperature and moisture and the late plantings produced as many beans as the early plantings except in the varieties susceptible to common bean mosaic.

SUMMARY

Sanilac, a new disease resistant pea bean was developed and released in 1956 through the cooperative arrangement of the Department of Farm Crops, Michigan State University Agricultural Experi-

ment Station and the Crops Research Division, Agricultural Research Service, United States Department of Agriculture.

The Sanilac bean is a selection from a 3-way cross in which a bush-type mutant bean developed by X-ray was the principal recurrent parent. Sanilac has outyielded Michelite in most tests conducted during 1953-1959, and when all overstate trials were compared, it averaged more than Michelite in nine of the principal bean-growing counties in Michigan.

Plants of Sanilac are upright, bush-type, vary from 14 to 21 inches in height, and produce a short determinate runner up to 14 inches in length. Large numbers of bloom are set over an extended period, beginning approximately 47 days after planting. The seed is round, uniform, white, and wrinkle free. Sanilac is a midseason variety that matures in about 88 days as compared to 95 days for Michelite.

The screenings and "pick" are considerably less for Sanilac than for Michelite. From the disease resistance viewpoint, Sanilac is superior. It is resistant to the alpha, beta, and gamma races of *Colletotrichum lindemuthianum* (anthracnose). It is resistant to common bean mosaic virus 1, and normally escapes infection by *Sclerotinia sclerotiorum* (sclerotinia wilt). Sanilac is resistant to halo blight but moderately susceptible to common and fuscous bacterial blight.

Sanilac is adapted for production under a wide range of climatic conditions. It was reselected in 1956 and a new seed lot increased in Idaho in 1957. This seed was grown for certification in 1959 and will gradually replace the present stock of Sanilac.

Sanilac produced significantly more beans in a 28-inch row than in rows spaced at 32 and 36 inches. There was no significant increase in yield for beans spaced 4 inches apart in the row as compared to 2 inches apart in the row. Significantly fewer beans were produced with the plants spaced 6 inches apart as compared to 2 or 4 inches.

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POULTRY SCIENCE RESEARCH AT THE UPPER PENINSULA EXPERIMENT STATION, Chatham, Michigan

III. A Self-serve Method of Retailing Eggs at the Farm

By L.R. CHAMPION and H. C. ZINDEL

DEPARTMENT OF POULTRY SCIENCE

INTRODUCTION

ONE OF THE MARKETING PROBLEMS which has continually confronted commercial egg producers is that of developing ways and means of efficiently merchandizing the eggs which they produce. Thus in recent years, the business aspect of commercial egg production — selling the products of labor to best advantage — has assumed its rightful place of importance in successful poultry enterprises.

Egg producers usually have a wide range of markets or outlets through which they can sell high quality eggs. Several decades ago, a considerable number of the eggs produced by the small flock owner were exchanged for groceries. Today, the bulk of the eggs produced are sold to wholesale buyers, as most poultrymen prefer to devote their time and efforts to producing eggs on a larger volume basis, rather than becoming involved in marketing problems. Presently, two of the most important marketing channels for eggs, in terms of volume, are the buying stations (frequently referred to as "intermediate outlets"), and producers' cooperative associations. Other channels of distribution available to the egg producer include: retail sales directly to the consumer, sales to "route" men or hucksters, grocery stores, hotels, restaurants, dairies, institutions, bakeries and local produce dealers. Under the system of marketing whereby retail sales are made directly to the consumer, the producer generally realizes the

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greatest return for his eggs. However, since the eggs must be candled, graded, cartoned, and in many cases delivered to the consumer, the increased costs for supplies, equipment and labor must be considered.

It is the purpose of this paper to report on a method of retail egg marketing which was initiated on November 13, 1958, and continued through April 30, 1960, at the Upper Peninsula Experiment Station, Chatham, Michigan.

LITERATURE REVIEW

Consumer Purchasing Practices

Mortenson and Graf (5) reported the following percentage shifts in types of egg sales by farmers in Wisconsin from 1941 to 1948: to retail stores—44.9 percent to 31.3 percent; to local plants and produce dealers—19.6 percent to 25.3 percent; to truckers—20.4 percent to 18.8 percent; direct sales to consumers—9.8 percent to 16.7 percent; to hotels, restaurants, bakeries and cooperative associations—5.3 percent to 6.9 percent. In small and medium-sized towns, sales from egg producers directly to consumers were common. In surplus egg-producing areas, direct consumer sales were not looked upon favorably for merchandizing large volumes of eggs.

Harper (1) found that most commercial eggs produced in Georgia were sold to "intermediate outlets", thence to retail stores for consumer purchase. Only 7 percent of the 40 producers studied in the Butler area of Georgia during 1950, retailed their eggs to consumers. The vast majority of the producers (52 percent) sold their eggs to the feed dealer-route men.

Roy (6) obtained survey data from 10 states in the Southern region of the United States and stated that Alabama workers reported that the profit from table eggs marketed directly to consumers was 5.4 cents per dozen, whereas the profit from sales to retailers and wholesalers was 2.1 and 0.8 cents per dozen, respectively. Therefore, despite the higher labor costs involved in making direct sales to consumers, greater profits were made. It was suggested that egg producers should not eliminate the possibility of performing, for themselves, all or part of the egg marketing functions.

Wright (8) obtained detailed sales records from 90 Michigan farms for the 1956-57 production year. He reported that those producers who retailed all or a part of their total production of eggs received 10 cents more per dozen than those producers who sold

only to commercial egg buyers. Return per hour of labor was 99 cents and 30 cents for those who retailed and those who sold to "commercial buyers," respectively.

Williams, et al. (7) pointed out that although some retail store managers maintain high egg quality through the employment of proper egg handling methods, other retail stores still use "methods used 30 years ago". Considering the proportion of eggs which are purchased at the farm or which are farm-delivered, these researchers suggested that many consumers may be dissatisfied with the quality of eggs sold in retail stores.

Moore (4) studied the egg buying practices of 721 families in the Rochester, New York area in 1952, and found that "the most important single source of eggs purchased by Rochester housewives was farmers." Fifty-three percent of the combined low, medium and high income family groups purchased eggs directly from the farmer, with only 35 percent of the families purchasing eggs from retail stores. This researcher also reported that in the Ithaca study, 52 percent of the housewives purchased their eggs from farmers and only 27 percent purchased eggs from grocery stores. Satisfaction with source of egg supply was given by 93 percent of the families as the reason for source of purchase. Further, freshness and quality were given as the most important factors considered when purchasing eggs by both the Rochester and Ithaca housewives. These data are in accord with those obtained in a study of consumer preferences, practices and demands in purchasing eggs by Columbus, Ohio, housewives, by Jasper and Cray (3).

MATERIALS AND METHODS

During the 1957-58 year of operation at the Upper Peninsula Experiment Station, a substantial portion of the 17,441 dozens of eggs produced were retailed directly to consumers from the service building by station personnel. Egg customers arrived at any time throughout the day, seven days a week, located the individual in charge wherever he might be, who in turn went to the service building, took the cartoned eggs in the size desired from the refrigerated holding room, wrote up the sale and then made change for the customer. In the majority of cases, poultry personnel had to stop whatever poultry chore they were performing to satisfy each and every on-the-farm customer. Further, additional conversation time was usually involved for each purchase.

In the light of this extremely unfavorable on-the-farm egg customer arrangement and because each sale took the worker away from caring for the birds, it was deemed advisable to try a different approach to direct consumer egg sales. A refrigerated egg display case, 46″ x 105″, as shown in Figures 1 and 2, was placed in the service building. One sign, 28″ x 28″, was designed and made-up with printed instructions for self-serve, on-the-farm egg customers. It was placed directly above the refrigerated display case. Each customer was requested to: 1) sign his or her name and address in a bound ledger, 2) mark down the number of dozens and the size of eggs being purchased, and 3) make his own change from an open cash box placed on a stand above the ledger. As an aid, a 3′ x 4′ blackboard was mounted on the wall and the prices for the various sizes of eggs were written in chalk for one to five dozens of eggs. All egg prices posted included a 3 percent Michigan sales tax. This procedure eliminated the

SERVE YOURSELF EGGS
EGG PRICE IS MARKED ON CARTON
INSTRUCTIONS:
1. Sign name and address in book
2. Mark down number and size of eggs taken
3. Leave cash in box
4. Take eggs
EGGS

Fig. 1. Refrigerated egg display case and sign with instructions to self-serve egg customers.

Fig. 2. Complete lay-out of self-serve area which shows the refrigerated egg display case, the sign with instructions for customers, egg prices, open cash box, ledger and table.

necessity of marking the price on each carton of eggs. The prices were changed periodically (when necessary) and based upon the Egg and Poultry Marketing News, Michigan Department of Agriculture.

A small metal table was provided for customer convenience, on which to place the eggs they had selected to purchase and on which they could tie several egg cartons together, should they so desire.

At the close of each day, the day's receipts were collected, counted and checked against the ledger. As indicated heretofore, the egg prices were changed each morning, if necessary, and the refrigerated display case was replenished.

The cost of the various merchandising items were as follows: refrigerated display case, $400.00; sign, $5.00; blackboard, $5.00; ledger, $2.00; cash box, $2.50; ball of tying cord, $1.35; metal table, $15.00; carton set-up machine, $11.70; egg grader, $169.50; and egg cartons, $24.40/M.

RESULTS AND DISCUSSION

Number of Dozens and Sizes of Eggs Purchased

The data presented in Table 1 shows the number of dozens of extra large, large, medium, small, and checks and dirties retailed through the "Honest George" self-serve facility at Chatham from November 13, 1958 through May 2, 1959, and from July 10, 1959 to May 1, 1960. Further, the total receipts and average prices received per dozen for eggs in the various classifications are presented. Over the period of "Honest George" operation – 467 days – 2,059 dozens of extra large eggs were retailed at an average price of 51.0 cents per dozen. The average price received per dozen for the 2,431 dozens of large eggs retailed was 48.1 cents. For medium and small eggs, the average prices received per dozen were 45.0 and 31.1 cents, with 2,375 and 1,225 dozens retailed, respectively. Checks and dirties (3,318 dozen) were sold at an average price of 26.8 cents per dozen. A grand total of 11,408 dozens of eggs were retailed on a self-serve basis on-the-farm, and total receipts over the 467 day period were $4,556.83. The average price received per dozen for all eggs sold was 39.94 cents. For the entire self-serve test-period, the average number of dozens of eggs merchandised each day was 24.43, the average daily receipts were $9.76, and the eggs merchandised on the self-serve basis represented 19.4 percent of the total eggs produced.

TABLE 1—On-the-farm self-serve egg sales, Chatham, Michigan, November 13, 1958—May 2, 1959 and July 10, 1959—May 1, 1960

	Extra large	Large	Medium	Small	Checks and dirties	Totals
Number dozens ..	2,059	2,431	2,375	1,225	3,318	11,408
Total Receipts, $.	1,049.67	1,168.77	1,067.70	380.71	889.98	4,556.83
Av. Price/Dozen, ¢	51.0	48.1	45.0	31.1	26.8	39.9

NOTE: a. Duration of test period—467 days.
b. Average number of dozens sold/day—24.43.
c. Average daily receipts—$9.76.
d. Average price received/dozen, less checks and dirties—45.3 cents.

Size of Individual Purchase

As shown in Table 2, there were 3,595 individual egg purchases. It is immediately apparent that two dozen lot purchases were the most important size of purchase, with purchases of one dozen, three

TABLE 2—Size of individual egg purchase—Chatham, Michigan. 1959-1960

Size	Number of individual sales	Percentage purchasing, dozens						
		1	2	3	4	5	6	More than 6
Extra large.....	654	19.4	34.1	14.7	15.4	7.0	5.7	3.7
Large.....	797	21.2	35.9	12.8	16.6	8.4	4.0	1.1
Medium.....	821	18.3	34.7	20.8	16.1	5.2	2.7	2.2
Small.....	403	25.1	26.5	19.8	18.6	7.0	1.5	1.5
Checks and dirties.	920	13.4	27.7	20.1	20.2	5.9	4.3	8.4
	3,595	18.6	32.2	17.7	17.4	6.6	3.8	3.7

dozen and four dozen lots ranking approximately the same in importance. Translating the pooled data in another manner, 81.4 percent of all purchases were for lots of two dozen or more.

From these data it is suggested that egg producers desirous of retailing eggs should not overlook multiple unit sales to move those sizes or qualities of eggs that are in apparent surplus at certain times of the year. Hoyt (2) also recommended multiple unit sales. Further, it is suggested that those egg producers who are actually engaged in, or those who contemplate an on-the-farm self-serve egg facility, should take a second look at the possibility of pricing eggs such that multiple unit sales will be in price units such as $1.00, $1.25, $1.50, and so on, thus possibly taking advantage of the effect of the important psychological factor on egg sales.

Wholesale vs. "Honest George" Retail Sales

Data on the number of dozens of extra large, large, medium and small eggs, total receipts by egg size classification, and average prices received per dozen of eggs, for graded and cartoned eggs wholesaled and delivered by the Department of Poultry Science to the Dairy Sales Room, M. S. U., for over-the-counter retail sales during the identical period of July 10, 1959 to May 1, 1960, are presented in Table 3. A comparison of the average prices received per dozen, by size, showed that the price differentials between eggs retailed on-the-farm on a self-serve basis at Chatham and wholesale prices received from the Dairy Sales Room were as follows: extra large, 8.0 cents; large, 6.4 cents; medium, 9.0 cents; and small, 5.1

TABLE 3—Wholesale sales by the poultry science department, M. S. U. to dairy sales room, M. S. U., July 10, 1959-May 1, 1960

	Extra large	Large	Medium	Small	Total
Number dozens	6,484	6,503	6,026	1,777	20,790
Total receipts, $	2,790.75	2,714.88	2,169.97	462.92	8,137.52
Av. Price/dozen, ¢	43.0	41.7	36.0	26.0	39.1
Difference from average price/dozen at Chatham	−8.0	−6.4	−9.0	−5.1	

cents. Logically, the price differentials were in favor of the self-serve retailing method. It should be noted that the mark-up on the wholesale price in all egg size categories by Dairy Sales Room was 5.0 cents per dozen. Therefore, the premium (the additional price received for eggs sold on-the-farm at Chatham as compared with the retail prices received at Dairy Sales Room, M. S. U.) per dozen was 3.0 cents for extra large eggs, 1.4 cents for large eggs, 4.0 cents for medium eggs, and 0.1 cent for small eggs. The labor charge of between 3.0 and 3.5 cents per dozen for cleaning, grading, and cartoning, plus the cost of the egg carton ($24.40/M) would be comparable under both types of sales, but the wages for Dairy Sales Room counter personnel must be considered as it is an additional item of expense in counter retailing methods. It is acknowledged that location affects price, especially where the surplus-deficit situation may be different.

Presented in Table 4 are data which show that the price advantage for extra large, large, medium and small eggs sold directly to the consumer on-the-farm at Chatham averaged 6.19 cents per dozen. Checks and dirties were not retailed over-the-counter at the Dairy

TABLE 4—Self-serve retail sales and wholesale sales of extra-large, large, medium and small eggs

	Wholesaled to dairy sales, M.S.U.	Self-serve retail, Chatham
Number dozens	20,790	8,090
Receipts, $	8,137.52	3,666.85
Average price/dozen, ¢	39.14	45.33
Price advantage, ¢/dozen	.....	+6.19

Sales Room and therefore, these data could not be included in the comparison. It is important to note that retail sales on-the-farm on a self-serve basis were an extremely important outlet for merchandising checked and dirty eggs; eggs which are not normally merchandised in retail outlets. Thus, egg producers who retail eggs on-the-farm should readily recognize that they have available to them an important marketing channel for checked and dirty eggs.

Implications

If it is assumed that an egg producer has a flock of 5,000 laying hens, and further, that the average egg production is 225 eggs per bird, a total of 93,750 dozens of eggs would be produced. It would appear that a reasonable proportion for the number of checks and dirties produced would be approximately 20 percent. Therefore, 75,000 dozens of eggs would fall into the extra large, large, medium and small size classifications. If all of the eggs were wholesaled at an average price of 39.14 cents per dozen (average price received per dozen of eggs wholesaled to M. S. U. Dairy Sales Room), the egg receipts would be $29,355.00, whereas if the eggs were retailed at an average price of 45.33 cents per dozen (the average price received per dozen of eggs retailed on a self-serve basis on-the-farm at Chatham) the egg receipts would be $33,997.50 – an additional return of $4,642.50, in favor of retailing. It would be highly illogical, in most cases, to presume that an egg producer with 5,000 laying females could retail the entire production of this number of layers through this type of sale. However, that proportion of the production which could be retailed on a self-serve basis on-the-farm would certainly constitute additional income.

Integrity of the Customer

A possible criticism of an unattended self-serve sales facility and an open cash box is that shortages of cartoned eggs and/or money may frequently occur. During the period of this operation only two shortages were noted, one of 24 cents, and one of 30 cents. On the day following the 30 cents shortage, the cash box checked out to be 30 cents over. One customer noted in the ledger that "I owe 3 cents". There were no shortages of eggs noted. Thus, the self-serve sales and open cash box operation has proved to be exceedingly satisfactory.

Frequency of Purchase

The signatures in the ledger were studied in an attempt to determine the frequency with which eggs were purchased. It readily became apparent that the duplication of family names and, in the majority of cases, the failure of the customers to give their address, made this analysis an impossibility. Wherever this information could be studied, it appeared that specific, identifiable customers regularly purchased eggs within a range of 4 to 7 days.

Special Features of the Area

Chatham is located in Alger County and this area is comparatively sparsely populated. The fact that in Alger County there are 913 square miles of land area (exclusive of water) and a population of 9,190[1] individuals emphasizes the lack of density of population. The largest city in the county is Munising (located about 17 miles northeast of Chatham) with a population of 4,205 individuals.

Marquette County, with a land area of 1,841 square miles and a population of 55,926 individuals, lies west of Alger County and has as its largest city, Marquette (population, 19,657). The city of Marquette is approximately 33 miles from Chatham.

The 15 counties in the Upper Peninsula of Michigan have a population of 325,279 individuals in a land area of 16,538 square miles, or 19.67 individuals per square mile. The largest county in terms of both land area and population is Marquette County. Houghton County ranks second in population (35,579).

Alger County reported a population of 12,000 hens and pullets and Marquette County reported a population of 12,500 hens and pullets on January 1, 1959. In the entire Upper Peninsula, the hen and pullet population was reported to be 275,000 hens and pullets, (Michigan Agricultural Statistics, July, 1959). Thus, it may readily be seen that this entire region is a deficit egg-producing area.

Distance Traveled to Purchase Eggs

Regular egg customers were identified as coming from Au Train (10 miles), Trenary (12 miles), Munising (17 miles), and as far away as Marquette, Palmer and Negaunee (33 to 35 miles). Twenty-two regular customers resided in Marquette. Church groups from Marquette made purchases on-the-farm at Chatham. The eggs purchased

[1]All population figures are preliminary 1960 Census Data.

by distant customers ranged in lots of from 4 to 15 dozens. It was observed that frequently the purchases of eggs were by family groups and that the purchases were on week-ends. It is suggested that the availability of fresh, high quality eggs prompted the repeatability of egg sales to those consumers residing at distant points.

CONCLUSIONS

Fresh, high quality graded eggs can be profitably merchandised on a self-serve basis on-the-farm. In the study reported herein, self-service egg sales represented 19.4 percent of the total eggs produced. The average price-advantage for extra-large, large, medium and small eggs sold directly to the consumer on-the-farm at Chatham was 6.19 cents per dozen, when compared with wholesale sales to the Michigan State University Dairy Sales Room. Further, retail sales on-the-farm were an extremely important outlet for merchandising checked and dirty eggs. Two dozen lot purchases were the most important size of purchase, with one dozen, three dozen and four dozen lots ranking approximately the same in importance. It is suggested that egg producers who engage in or contemplate an on-the-farm, self-serve facility should seriously consider pricing eggs such that multiple unit sales will be in $1.00, $1.25, $1.50, and so on, price units, thereby taking advantage of any possible psychological factor effect on egg sales. Self-serve sales and an open cash box did not result in losses of eggs and or money. The regularity of purchases ranged from four to seven days. Twenty-two of the regular egg customers drove 33 to 35 miles to purchase eggs, with size of purchase ranging from four to 15 dozen. Week-end purchases by family groups were evident. It is suggested that fresh, high quality eggs, in all probability, account for the repeatability of sales to customers residing at distant points. In totality, the evidence from this study emphatically points out that egg producers should not over-look the possibility of establishing, what may well prove to be, a profitable on-the-farm self-serve facility for merchandising eggs.

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CONSUMER PREFERENCES FOR TURKEYS WITH VARIOUS GRADE LABELS[1]

By W. C. MILLS, JR.,[2] L. E. DAWSON and H. E. LARZELERE

DEPARTMENTS OF POULTRY SCIENCE AND AGRICULTURAL ECONOMICS
MICHIGAN STATE UNIVERSITY, EAST LANSING, MICH.

MANDATORY GRADE LABELING of turkeys is receiving much discussion within the turkey industry. Before such a program can be adequately evaluated, it will be necessary to agree on how turkeys should be labeled; or, which grade labels have the highest psychological significance of quality and who should evaluate quality and who should determine how this quality should be labeled.

The present ABC system of grading turkeys is based on arbitrary technical quality standards with no consideration apparently being given to the nutritive value of turkey meat. Who can say authoritatively that a turkey classified as A quality is better than B quality when there is no known difference in the nutritive value of the two? Naturally a dilemma arises as to whether the present system should be continued or if another system of grading would be better.

The specific objectives of this experiment were: a) to determine if consumers prefer the present system (ABC) or a system embracing word grade labels such as Prime, Choice, Good, and Commercial; b) to discover the characteristics of turkeys that consumers consider as quality determinants.

In this experiment, the authors were primarily concerned with grade labels although some price labels were used to observe the effect of price on consumer evaluation.

The authors define quality as that combination of attributes that have significance in determining the degree of acceptability of a product. In defining quality in this manner, the authors also accept the assumption that consumers should evaluate quality and determine how it is to be labeled.

With this definition in mind, the experiment was designed to test

[1]The authors gratefully acknowledge the partial support of this study by the National Turkey Federation.

[2]Now at North Carolina State College, Raleigh, North Carolina.

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the hypothesis that appearance (excluding price) is the main factor upon which turkey purchases are based; each consumer will purchase (when selecting between turkeys of comparable quality) the turkey labeled with the grade label which has the highest perceived quality meaning to him. The problem, then, is to interpret the quality meaning which is most acceptable to a substantial proportion of consumers.

Makens[3] reported that personal inspection was a major determinant in the selection of turkeys, and that grade labels Prime, Choice and Good were preferred to letter grade labels A, B and C. This work did not test the preference for word grades when different prices were used in conjunction with grade labels. A search of the literature failed to reveal any studies pertaining to word vs letter grades on turkeys.

PROCEDURE

The Detroit Preference Panel was used to secure consumer opinions, attitudes and preferences for turkeys labeled with various grade labels and prices. Panel members (male and female) came to Wayne State University, Detroit, Michigan and evaluated turkeys for acceptability and ranked them in order of preference, from most to least acceptable, when various grade labels were used. For further information regarding the selection and operation of this panel, see Larzelere and Gibb[4].

Twenty-five series[5] of turkeys were evaluated during a period of eight months using grade labels Prime, to correspond with Grade A; Choice with Grade A or B; Good with B; and Commercial with C. The various labels were alternated between individual turkeys and groups of turkeys to test the hypothesis further.

When prices were used, the Detroit retail price for Grade A turkeys was the base price. Price differences of two and three cents per pound were used between samples in the same series. In some series the letters U. S. preceded the grade label; when this occurred, it is indicated in the appropriate table.

A sales test was conducted to check the validity of the results of the Detroit Preference Panel. For complete information regarding the sales test, see Mills[6].

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[3]Makens, J. C., 1960. An evaluation of mandatory grade and sex labeling of turkeys. Master's thesis, Mich. State Univ., East Lansing, Mich.

[4]Larzelere, H. E. and R. D. Gibb, 1956. Consumer opinion of quality in pork chops. Mich. Agr. Expt. Sta. Quart. Bul. 39(2): 327-333.

[5]"Series" refers to two or more turkeys in a single display for evaluation and ranking.

[6]Mills, W. C., Jr., 1960. A study of word vs. letter grading of turkeys. Master's thesis, Mich. State Univ., East Lansing, Mich.

RESULTS

The turkeys in Series I were labeled as to quality represented. The turkey labeled Prime was high A quality; Choice was B quality due to a moderate size breast bruise; and Commercial was B quality due to pin feathers and a small breast bruise. Choice and Commercial labels were reversed before evaluations were made in the evening. See Table 1.

TABLE 1—Series I and II. Influence of grade label and price on preference for turkeys by the Detroit preference panel, May, 1959

Series I (afternoon)			Series II (evening)		
Grade label	Cents/lb.	Percent first place	Grade label	Cents/lb.	Percent first place
U. S. Prime.....	.39	68.7	U. S. Prime.....	.39	47.6
U. S. Commercial(*a*)	.33	27.1	U. S. Choice(*a*)....	.36	46.3
U. S. Choice(*a*)....	.36	4.2	U. S. Commercial(*a*)	.33	6.1

(*a*) The labels on the turkeys labeled U. S. Choice and U. S. Commercial were reversed before the evening panel evaluations were made.

The bird labeled U. S. Commercial in the afternoon was ranked first by 27 percent of the panel members. This same bird, labeled U. S. Choice in the evening, was ranked first by 46 percent of the panel. This indicates a significant effect of the grade label.

The panel members rejected the bird with the breast bruise (U. S. Choice in the afternoon and U. S. Commercial in the evening). This rejection because of moderate size breast bruise was evidenced throughout the study.

Statistical analysis (coefficient of concordance) showed that the panel members had a community of preference in their evaluation of these samples. This does not mean that there is necessarily a significant difference between any two samples within a series[7].

Although the same grade labels were used in Series III, as in Series I and II, the turkeys were different. The turkey labeled Prime was top A quality; the turkey labeled Choice was A quality except for small bruises; the turkey labeled Commercial was lacking in flesh. Results are shown in Table 2.

Rankings (including 1st, 2nd, and 3rd choice) in Series I, II and III

[7]Kendall, M. G., 1955. *Rank Correlation Methods.* Hafner Pub. Co., New York. pp 95-105.

TABLE 2—Series III. Influence of grade label on preference for turkeys by the Detroit preference panel, afternoon and evening, June, 1959

Grade label	Percent first place	Rank		
		1	2	3
		Persons		
U. S. Prime	57.1	64	29	19
U. S. Choice	36.6	41	49	22
U. S. Commercial	6.3	7	15	70

were in significant agreement at the 1 percent level and support the original hypothesis.

In Series IV hen turkeys were labeled with several grade labels, which were changed after the afternoon panel members had made their evaluations. The turkeys labeled Grade A and Prime were high A quality and their labels were reversed before the evening panel met. Turkeys labeled Grade B or Choice were low A or high B quality and were also reversed. Panel evaluation results are shown in Table 3.

TABLE 3—Series IV and V. Influence of grade label on preference for turkeys by the Detroit preference panel, afternoon and evening, June, 1959

Afternoon grade label	Percent first place	Evening grade label	Percent first place
U. S. Grade A	51.1	U. S. Prime	55.2
U. S. Prime	35.6	U. S. Grade A	26.9
U. S. Choice	6.7	U. S. Grade B	11.9
U. S. Grade B	6.7	U. S. Choice	9.0

While the difference in percentage of first preference between the Grade A and Prime is significant, there was no significant difference in the total rankings of these two turkeys. No significant difference in the percentage of first preference between the turkey labeled Choice and Grade B was found. There was a significant difference in total ranking between them in favor of the turkey labeled Choice. Rankings as a group are in significant agreement at the 1 percent level.

Reported in Table 4 are results from Series VI. Turkeys labeled Prime and Grade A were of comparable A quality while those labeled Choice and Grade B were of comparable B quality.

TABLE 4—Series VI. Influence of grade label on preference for turkeys by the Detroit preference panel, afternoon, October, 1959

Grade label	Percent first place	Rank			
		1	2	3	4
		Persons			
U. S. Prime	59.3	35	17	4	3
U. S. Grade A	28.8	17	22	19	1
U. S. Grade B	3.4	2	6	13	38
U. S. Choice	8.5	5	16	23	15

The preference for the turkey labeled U. S. Prime is obvious at first glance. However, the preference for the turkey labeled U. S. Choice when compared to Grade B becomes most obvious when you note the number of people ranking the turkey labeled U. S. Choice as second or third.

The results of this series support the original hypothesis, and the rankings are in significant agreement at the 1 percent level.

To evaluate the grade label preferences for toms in relation to hens, tests were conducted using the same grade labels with sex identification. In Series VII the hens were comparable A quality, and the toms were comparable A quality. Results are shown in Table 5.

The turkeys labeled U. S. Prime ranked high in percentage of first preference. The rankings of this class are in significant agreement at the 1 percent level.

TABLE 5—Series VII. Influence of grade label on preference for turkeys by the Detroit preference panel, afternoon, June, 1959

Grade label	Percent first place	Rank			
		1	2	3	4
		Persons			
U. S. Grade A Hen	22.2	10	23	5	7
U. S. Prime Hen	42.2	19	9	12	5
U. S. Prime Tom	26.7	12	7	17	9
U. S. Grade A Tom	6.7	3	6	12	24

In the evening evaluation of this series, the labels were reversed between the hens and between the toms. No other changes were made. The preference results due to this change are reported in Table 6.

TABLE 6—Series VIII. Influence of grade label on preference for turkeys by the Detroit preference panel, evening, June, 1959

Grade label	Percent first place	Rank			
		1	2	3	4
		Persons			
U. S. Prime Hen.....	53.7	36	18	8	5
U. S. Grade A Hen.....	22.4	15	31	14	7
U. S. Grade A Tom.....	16.4	11	4	21	31
U. S. Prime Tom.....	9.0	6	16	24	21

In the afternoon (Table 5) one hen was preferred most often. In the evening, with the labels reversed, another hen was preferred; and, in each case, it was the hen labeled Prime.

The difference between the rankings of the toms in the afternoon (Table 5) was significant; however, in the evening section, the difference was not significant. This indicates that one of the toms was perceived to be of better quality and that the label Prime was most preferred.

The results of both of these sections of the panel support the original hypothesis. Rankings are in significant agreement at the 1 percent level.

Preferences for turkeys labeled with grade labels, as used in Series VII and VIII, were later retested using different turkeys of comparable A quality. These results are shown in Table 7. Rankings are in significant agreement at the 1 percent level.

The panel members failed to rank the turkey labeled Prime tom over the turkey labeled Grade A tom. This indicates that the panel members perceived the Grade A tom to be of superior quality as compared to the turkey labeled Prime tom which supports the original hypothesis.

To determine the relationship between price and grade label on consumer preference, tests were conducted using labeled turkeys with price differences. Turkeys labeled Prime and Grade A were A

TABLE 7—Series IX. Influence of grade label on preference for turkeys by the Detroit preference panel, afternoon and evening, October, 1959

Grade label	Percent first place	Rank			
		1	2	3	4
		Persons			
U. S. Grade A Hen.....	22.7	27	42	30	17
U. S. Prime Hen.....	47.1	56	23	20	17
U. S. Grade A Tom.....	21.8	26	30	30	30
U. S. Prime Tom.....	8.4	10	23	35	48

quality; those labeled Choice and Grade B were B quality. Results of Series X are shown in Table 8.

These data show that the turkey labeled Prime was preferred over the turkey labeled Grade A. They also show that Choice was preferred over Grade B as a grade label for turkeys, and that a higher percentage of the panel members preferred a high B quality turkey labeled Choice than preferred an A quality turkey labeled Grade A when the price differential was 3 cents per pound. Only one person ranked the turkey labeled Choice as being fourth, whereas 21 ranked the Grade A turkey as fourth.

TABLE 8—Series X. Influence of grade label and price on preference for turkeys by the Detroit preference panel, evening, May, 1959

Grade label	Cents per pound	Percent first place	Rank			
			1	2	3	4
			Persons			
U. S. Grade A Hen.....	39	4.9	4	20	37	21
U. S. Grade B Hen.....	36	9.8	8	7	14	53
U. S. Prime Hen.....	39	48.8	40	17	18	7
U. S. Choice Hen.....	36	36.6	30	38	13	1

The results of Series XI using both hens and toms with price differences are shown in Table 9. In this series the hens were of comparable A quality. The tom labeled Grade A was slightly red, and the tom labeled Prime was in a bag which was torn at the wing and tail. Other factors such as fleshing, finish, and conformation were comparable.

Total rankings as well as the percentages of first preference were

TABLE 9—Series XI. Influence of grade label and price on preference for turkeys by the Detroit preference panel, afternoon and evening, May, 1959

Grade label	Cents per pound	Percent first place	Rank			
			1	2	3	4
			Persons			
U. S. Grade A Tom.....	36	9.6	13	11	41	64
U. S. Grade A Hen.....	39	19.8	27	63	19	30
U. S. Prime Tom.....	36	13.2	18	21	52	38
U. S. Prime Hen.....	39	57.4	78	33	16	2

in agreement during this series. The first preference is for the turkeys labeled U. S. Prime.

The data show that hens are more preferred by consumers than are toms. Rankings were in significant agreement at the 1 percent level.

In the following series (XII-XIV), each class of turkeys consisted of two groups of two turkeys each, and each group contained some variation; but, the variation within one group (in the authors' opinions) did not exceed the variation within the other group in the same class.

Series XII was set up to determine if the best of turkeys offered as A quality can be selected, labeled as "Prime" and sold at a premium price when the remaining A quality turkeys are labeled as "Choice". The results of this series are shown in Table 10.

The data indicate that the consumer perceived the word "Prime" and "Choice" as being practically equal in their quality connotation. The preferences are not statistically significant at the 5 percent level; however, from a sales standpoint the fact that over 45 percent of the

TABLE 10—Series XII. Influence of grade label and price on preference for turkeys by the Detroit preference panel, February, 1960

Class	Label	Cents per pound	Percent first place	Label	Cents per pound	Percent first place	Percent no choice*
A(*a*).....	Prime	..	44.1	Choice	..	52.5	3.4
E(*b*).....	Prime	47	45.6	Choice	45	51.9	2.5

(*a*) A = Afternoon—59 panel members.
(*b*) E—Evening —79 panel members.

*The report cards of 2 panel members were unusable. In some series one or two panel members were unable to make a decision of first preference, which explains the fluctuation in percent no choice.

panel members preferred the turkeys labeled Prime at two cents per pound higher than the turkeys labeled Choice is significant. The data indicate that a selected portion of turkeys now being marketed as Grade A can be sold at higher prices when they are labeled Prime and the remaining A quality turkeys are labeled Choice. Price studies would be needed to further test these results and to determine the amount of premium that could be expected.

Two classes were set up to determine whether consumers would purchase turkeys labeled Choice that were B quality because of small bruises, small areas of missing skin, processing defects, and a few scattered pin feathers. These turkeys were A quality flesh and finish. The turkeys within these two classes were comparable B quality.

The results indicate that consumers will accept Grade B turkeys of good flesh and finish but with minor defects when such turkeys are labeled Choice (Table 11). This acceptance is conclusively shown by the vast majority selecting the turkeys labeled Choice as compared to similar turkeys labeled Grade B. Preference for the turkeys labeled Choice increased by 5.4 percent when priced 2¢ per pound higher than those labeled Grade B.

TABLE 11—Series XIII. Influence of price and grade label on preference for turkeys by the Detroit preference panel, February, 1960

Label	Cents per pound	Percent first place	Label	Cents per pound	Percent first place	Percent no choice
Choice(*a*).....	...	89.8	Grade B	...	6.7	3.4
Choice(*b*).....	.41	89.9	Grade B	.41	5.1	5.0
Choice(*a*).....	...	89.8	Grade B	...	5.1	5.1
Choice(*b*).....	.43	96.2	Grade B	.41	1.3	2.5

(*a*) Afternoon—59 panel members.
(*b*) Evening —79 panel members.

The differences between Choice and Grade B labeled turkeys are significant at the 1 percent level.

Previous tests showed that consumers prefer the grade label Choice to Grade B. The following classes were set up to determine the relative quality meaning of the grade label Good vs Grade B when they are compared to the grade label Choice.

In this test the turkeys labeled Choice were A quality. The turkeys

labeled Good and Grade B were comparable B quality due to small breast bruises, pin feathers and damaged package materials. Results of this series are shown in Table 12.

TABLE 12—Series XIV. Influence of grade label and price on preference for turkeys by the Detroit preference panel, February, 1960

Label	Cents per pound	Percent first place	Label	Cents per pound	Percent first place	Percent no choice
Choice(*a*).....	...	79.7	Good	...	17.0	3.4
Choice(*b*).....	.45	65.8	Good	.43	31.6	2.5
Choice(*a*).....	...	78.0	Grade B	...	15.2	6.8
Choice(*b*).....	.45	78.5	Grade B	.43	18.9	2.5

(*a*) Afte-noon—59 panel members.
(*b*) Evening —79 panel members.

The data show that with the use of the grade label Good, 31.6 percent of the panel members ranked these turkeys as first preference (compared to 18.9 percent for the Grade B label) when the price difference was 2¢ per pound. Results show that the grade label Good is preferred to the label Grade B.

The data also show that when there was price difference, the percentage of panel members selecting turkeys labeled Choice decreased when compared with those turkeys labeled Good; whereas, when comparable turkeys labeled Choice are compared to turkeys labeled Grade B, the percentage of panel members preferring Choice increased slightly when the price difference was 2¢ per pound.

Following a sales study in which turkeys labeled Prime, Choice and Grade A were retailed in three Lansing stores, a sample of Beltsville broiler-fryer turkeys of similar apparent quality were displayed and evaluated by the Detroit Preference Panel. Turkeys labeled Prime were also labeled at 43 cents per pound; those labeled Choice—41 cents; and those labeled Grade A—39 cents. Preference results are reported in Table 13.

Although certain panel members preferred each of the three turkeys, the highest percentage of panel members again preferred the turkey labeled Prime. These results are in agreement with the results of the actual sales test[8].

[8]Mills. op. cit. footnote 6.

TABLE 13—Influence of grade label and price on preference for turkeys by the Detroit preference panel, April, 1960, labeled as in sales test (Mills)

Grade label	Cents per pound	Rank			Percent of first place
		1	2	3	
Afternoon					
Prime	43	30	7	18	54.5
Choice	41	15	31	8	27.3
Grade A	39	10	18	27	18.2
Evening					
Prime	43	24	19	23	36.4
Choice	41	24	31	11	36.4
Grade A	39	18	16	32	27.2
Afternoon					
Prime	41	33	10	13	58.9
Grade A	39	19	29	8	33.9
Choice	39	4	20	32	7.2
Evening					
Prime	41	25	19	22	37.9
Grade A	39	22	22	11	33.3
Choice	39	8	25	33	12.1

No changes were made in labeling from afternoon to evening sections.

DISCUSSION

Perhaps the main problem in establishing grade standards is that they must be based upon characteristics that consumers recognize and use in evaluating quality of a product. This is especially true in relation to food products.

In this study, to determine what characteristics consumers consider quality determinants of turkeys, it was evident that quality and value of a product is nothing more than what the individual perceives as value and quality. Throughout this study the panel members were, apparently, little concerned with minor defects. They demonstrated that discolorations due to moderate size flesh bruises, and lack of flesh

were the two main factors causing turkeys to be less acceptable. This rejection was consistent, even when the preferred word grade labels were used.

In all but one test, word grade labels were preferred to the letter grade labels A, B and C. This preference was highly significant from a statistical point of view, which indicates that the consumers prefer word grade labels Prime, Choice and Good.

When turkeys labeled with word grade labels were increased in price over turkeys labeled with letter grades, preferences for the turkeys labeled with word grade labels usually increased.

Purchases of turkeys during the sales test proved that the results of the Detroit Preference Panel were valid. The reliability of the Detroit Preference Panel was adequately shown in the results.

CONCLUSIONS

Based on the results of this study, several conclusions can be drawn.

1. Consumers prefer word grade labels Prime and/or Choice to letter grade A. They prefer Choice as a grade label over Good and Grade B, and they prefer Good to Grade B as a grade label.
2. Discolorations due to moderate size flesh bruises and lack of flesh are two defects which consumers consider when making a selection of turkeys.
3. Appearance (excluding price) is the main factor upon which consumers base their purchase of turkeys.
4. A major revision of the present turkey standards of quality is needed so that the standards will more accurately describe turkey quality as the consumer perceives turkey quality. Consumers indicated, during this study, that they rate a turkey labeled Grade B very low but they will rate the same turkey high if it is labeled Good or Choice.
5. It would be both desirable and profitable if the turkey industry would change the present system of grading turkeys to word grade labels such as those used in this study. This change would give consumers turkeys labeled in a manner that is preferred, and that is apparently more meaningful.

CHEMICAL COMPOSITION, COEFFICIENTS OF DIGESTIBILITY, AND TOTAL DIGESTIBLE NUTRIENT CONTENT OF CORN SILAGES

By C. F. HUFFMAN and C. W. DUNCAN

DEPARTMENTS OF DAIRY AND AGRICULTURAL CHEMISTRY

THE MOST IMPORTANT silage crop produced in the state of Michigan is made from corn. Almost 3 million tons are produced annually. According to statistics supplied by the Michigan Department of Agriculture (1), the yield of corn silage in 1958 was 8.3 tons per acre, equivalent to 2.5 tons of dry matter, whereas only 1.4 tons of dry matter was produced as hay. In addition to a larger yield of dry matter per acre, a pound of dry matter in corn silage is more nutritious than a pound of dry matter in hay (6 and 7). The increased yields of corn per acre have been due primarily to improved plant breeding, methods of fertilization, and cultural practices.

The purpose of this paper is to call the attention of livestock men to the strong and weak points in feeding corn silage. Corn silage, for example, is a cheap source of productive energy; the most costly part of the livestock ration. On the other hand, corn silage is relatively low in protein and may be low in calcium and carotene (provitamin A).

EXPERIMENTAL

Corn silage has been fed to dairy cattle at Michigan State University since 1881, but research in this area did not start until the introduction of hybrid corn in 1940 and has been continued through the 1956 crop. Table 1 presents the proximate chemical composition, pH, and yields per acre both as silage and as corn grain. The methods used for determining the yields have been described previously (6).

The mineral composition (calcium, Ca; phosphorus, P; magnesium, Mg; potassium, K; iron, Fe; copper, Cu; manganese, Mn; and cobalt,

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Co) and the carotene content were determined on most of the corn silages and are presented in Table 2. The eight silages that are starred in Tables 1 and 2 were used in digestion trials to determine the coefficients of digestibility. Table 3 includes the body weight of each cow used in the digestion trials, the amount of silage dry matter consumed per day, the length of the preliminary silage feeding and fecal collection periods, and the coefficients of digestibility obtained for dry matter, crude protein, ether extract, crude fiber, nitrogen-free extract (NFE), and total digestible nutrients (TDN).

TABLE 1—Proximate composition, pH, and yields of silage and corn grain per acre

Crop year	No. of samples	Dry matter (D.M.)	Ash	Crude protein	Ether ext.	Crude fiber	NFE	pH	Yield as:	
									Silage	Grain
		(%)	(%)	(%)	(%)	(%)			(tons)	(bu.[1])
1940*.....	2	28.6	1.61	2.63	1.32	5.62	17.4	4.4	....	....
1941.....	2	30.8	2.51	4.55	1.18	9.72	12.8	4.2	....	....
1942.....	6	27.6	1.41	2.18	0.73	6.15	17.1	4.4	....	....
1943.....	7	28.3	1.35	2.69	0.78	4.88	18.6	4.4	....	....
1944.....	3	25.2	1.58	2.69	0.84	5.57	14.5	4.1	....	....
1945.....	3	30.2	1.66	2.67	1.04	6.08	18.8	3.9	10.3	61.7
1946*.....	2	31.8	1.65	4.73	1.07	6.12	18.2	4.1	5.2	24.9
1947.....	1	32.8	1.65	2.76	1.14	7.28	20.0	4.0	....	....
1948.....	2	29.7	1.16	2.78	0.97	5.86	18.9	3.8	12.9	58.8
1949.....	3	27.5	1.29	2.02	0.97	5.86	17.4	3.7	12.3	47.3
1950.....	4	29.4	1.49	2.20	1.06	6.03	18.6	3.8	11.6	55.0
1951*.....	4	27.9	1.18	2.36	1.11	6.00	17.3	3.7	10.6	42.1
1952*.....	4	30.7	1.28	2.72	1.09	5.89	19.7	3.8	8.2	50.4
1953*.....	8	30.9	1.24	2.68	1.01	6.29	19.7	3.8	10.7	57.8
1954*.....	7	28.5	1.22	2.13	0.93	6.37	17.9	3.9	15.0	70.2
1955*.....	5	29.0	1.32	2.70	0.98	6.41	17.6	3.8	12.4	59.1
1956*.....	6	26.5	1.10	2.06	0.80	5.51	17.0	....	17.9	65.8
Average.....		29.1	1.45	2.74	1.00	6.21	17.7	4.0	11.6	53.9
Average[2].....		100.0	5.0	9.4	3.4	21.3	60.8	....	....	....
Morrison (1956).....		27.6	1.6	2.3	0.8	6.7	16.2			
Morrison[2].....		100.0	5.8	8.3	2.9	24.3	58.7			
Schneider (1947)....		23.8	1.5	1.8	0.7	6.4	13.4			
Schneider[2].....		100.0	6.3	7.6	2.9	26.9	56.3			
NAS-NRC (1958)...		25.6	1.5	2.1	0.8	6.4	14.7			
NAS-NRC[2].....		100.0	6.0	8.3	3.0	25.1	57.6			

[1]Based on 14 percent moisture content.
[2]Expressed on moisture-free basis.
*Used in digestion experiments.

RESULTS AND DISCUSSION

Proximate Composition

The data presented in Table 1 are given on the "as fed" or wet basis; however, the average values are given on both the wet and dry basis for comparative purposes with corn silage data (all analyses) published by Morrison (11), Schneider (14) and the National Academy

TABLE 2—Mineral and carotene content of corn silages

Crop year	No. of samples	Ca	P	Mg	K	Fe	Cu	Mn	Co	Carotene
		(%)	(%)	(%)	(%)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
1940*.....	2	0.052	0.065	0.065	....	..	..	..	....	....
1941.....	1	.....	0.077	0.102	....	..	..	..	0.11	....
1942.....	6	0.074	0.068	0.070	....	40	1	5	0.04	....
1943.....	6	0.059	0.069	0.080	0.33	54	2	7	0.02	4.0
1944.....	3	0.073	0.088	0.099	....	201	16	10	0.02	3.6
1945.....	3	0.059	0.084	0.059	0.32	147	2	7	0.03	5.0
1946*.....	2	0.093	0.109	0.113	....	54	3	8	0.03	5.0
1947.....	1	0.107	0.063	0.075	0.32	108	4	9	0.02	2.1
1948.....	2	0.094	0.065	0.073	0.34	28	5	11	0.02	3.7
1949.....	3	0.080	0.052	0.058	0.24	27	2	7	0.03	3.8
1950.....	2	0.071	0.080	0.064	0.32	55	2	5	0.03	4.5
1951*.....	2	0.086	0.061	0.083	0.26	29	2	6	0.03	10.8
1952*.....	3	0.056	0.084	0.075	0.40	40	3	5	0.02	3.9
1953*.....	2	0.062	0.066	0.073	0.34	37	2	12	0.02	7.0
1954*.....	2	0.074	0.057	0.072	0.30	42	6	9	0.03	6.8
1955*.....	3	0.093	0.058	0.086	0.56	44	5	7	0.02	9.3
1956*.....	1	0.062	0.055	0.062	0.29	32	2	7	0.03	....
Average.....		0.075	0.071	0.077	0.34	63	4	8	0.03	5.3
Average[1].....		0.26	0.24	0.26	1.17	216	14	27	0.10	18.2
Morrison (1956).....		0.10	0.07	0.05	0.30	30	1	19	....	12.8
Morrison[1].....		0.36	0.25	0.18	1.09	109	4	69	....	46.4
NAS-NRC (1958)...		0.08	0.06	0.06	0.29	51	3	13	0.02	11.6
NAS-NRC[1].....		0.33	0.23	0.24	1.15	200	10	49	0.08	45.5

[1]Expressed on moisture-free basis.
*Used in digestion experiments.

of Sciences-National Research Council (NAS-NRC, 1958). The dry matter content of the corn silages reported in this paper ranged from 25.2 to 32.8 percent (average 29.1) compared to 27.6, 23.8, and 25.6 for Morrison, Schneider, and NAS-NRC, respectively. The higher dry matter value may have been due to the maturity of the corn when put into the silo since mature corn would have a higher dry matter content than less mature corn.

The crude protein values ranged from 2.02 to 4.73 percent (average 2.74) or from 7.3 to 14.9 percent (average 9.4) on the dry basis. This latter value is much higher than the average values of 8.3, 7.6, and 8.3 percent, reported by Morrison, Schneider, and NAS-NRC, respectively. The NAS-NRC crude protein values varied from 3.5 to 15.9 percent on the dry basis.

If a 1,200-pound cow received 60 pounds of corn silage per day which contained 2.02 percent crude protein, she would consume 1.21 pounds of protein, or 0.64 pounds of digestible protein (1.21 x 53, average digestion coefficient for crude protein, Table 3). This amount of protein is just under the protein requirement (0.70 pounds) for maintenance of dairy cattle (10). The same intake of corn silage containing 2.74 percent protein would only supply 1.64 pounds of protein, or

0.87 pounds of digestible protein, which would supply enough digestible protein for maintenance and only enough for the production of 3.8 pounds of 4 percent fat-corrected milk (10). It is evident that an all-corn silage ration should be supplemented with protein concentrates, legume hay, or mixtures of hay containing an appreciable amount of legumes.

The two high protein values (4.55 and 4.73 percent) were obtained in 1941 and 1946. Both of these years had the lowest total rainfall for the months of July, August, and September. Haigh and Hogan (5) reported a crude protein value of 11.3 percent, on the dry basis, for drought corn silage grown on upland soil. Loomis (9)

TABLE 3—Daily intake of corn silage dry matter and the coefficients of digestibility obtained for 8 silage crops

Crop year	Cow No.	Wt. of cow	Daily D.M. intake		Silage periods		Dig. protein	Coefficients of digestibility						TDN
					Prelim.	Collection		D.M.	O.M.	Protein	Ether ext.	Crude fiber	NFE	
		(lb.)	(lb.)		(days)	(days)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
1940..	1	937	17.1	1.82	10	10	5.4	69.4	72.3	58.1	82.0	62.4	74.7	72.7
	2	1,009	17.1	1.69	10	10	5.4	71.7	74.7	59.1	87.2	67.6	76.5	75.6
1946..	1	886	15.2	1.72	14	7	7.1	65.5	65.3	50.4	71.3	59.6	71.7	65.7
	2	914	15.2	1.66	14	7	8.3	68.9	68.8	51.2	72.7	66.7	75.0	72.5
	3	992	15.2	1.53	14	7	7.4	70.0	69.7	53.1	74.5	66.5	76.1	67.3
	4	912	15.2	1.67	14	7	7.2	69.4	69.2	51.8	62.9	62.9	75.2	67.4
1951..	1	1,022	13.3	1.30	14	7	4.2	65.9	69.4	49.3	71.1	61.4	73.4	69.7
	2	1,078	13.3	1.23	14	7	4.0	66.7	68.8	47.6	75.0	60.1	72.7	69.1
1952..	1	1,070	13.8	1.29	14	7	4.3	67.1	68.5	48.7	65.3	61.6	73.7	68.4
	2	964	13.8	1.43	14	7	4.3	68.0	66.7	49.0	67.1	62.6	75.2	69.9
	3	923	13.8	1.50	14	7	4.4	65.7	66.2	50.5	66.2	57.9	72.7	67.4
1953..	1	1,092	15.3	1.40	19	7	5.1	63.7	65.2	57.6	69.0	58.1	69.3	66.1
	2	731	11.7	1.60	19	7	4.8	70.1	68.7	53.6	65.6	66.8	75.6	71.3
1954..	1	748	11.5	1.54	28	7	4.2	70.1	68.7	47.1	78.4	68.8	76.4	71.8
	2	725	11.0	1.52	28	7	3.9	68.8	67.3	43.9	71.4	65.8	76.1	69.4
	3	1,087	14.5	1.33	28	7	4.2	63.9	62.2	46.9	65.4	57.8	78.7	69.3
	4	1,031	14.5	1.41	28	7	4.6	66.4	64.8	51.6	78.2	60.2	70.7	66.8
1955..	1	1,110	14.0	1.26	19	7	5.4	66.5	68.4	55.8	75.0	63.0	72.3	68.4
	2	984	14.0	1.42	19	7	5.2	66.4	68.6	54.3	75.0	61.8	73.1	68.4
	3	885	13.2	1.49	19	7	5.7	64.8	68.1	59.7	68.4	61.4	69.6	66.3
	4	819	13.2	1.61	19	7	5.7	66.3	68.0	59.7	71.0	62.1	71.6	67.8
	5	848	13.2	1.56	19	7	5.0	67.8	69.1	62.9	71.0	64.4	72.4	68.1
	6	796	13.2	1.66	19	7	6.0	67.7	69.1	62.1	71.0	64.8	72.4	69.1
1956..	1	1,118	16.1	1.44	14	7	4.3	66.1	68.4	52.6	87.0	53.4	74.5	68.6
	2	1,190	16.1	1.35	14	7	3.9	58.8	61.5	48.1	85.2	40.9	68.9	62.0
	3	1,126	13.4	1.19	14	7	4.1	60.3	62.7	49.6	81.5	45.1	69.1	63.7
	4	1,100	16.1	1.46	14	7	4.3	67.5	69.5	52.3	81.8	57.3	74.9	70.3
Average							5.1	66.8	67.8	52.8	73.7	60.8	73.4	68.6
Morrison's average (1956)							4.3	....	....	54.0	75.0	65.0	70.0	66.3
Schneider's average—cattle (1947)							3.4	....	67.0	45.0	70.0	64.0	69.0	64.0
Schneider's average—sheep							4.2	....	66.0	47.0	71.0	64.0	68.0	63.3

reported that the stalks of normal corn contained 5.1 percent crude protein on the dry basis, whereas drought-injured stalks contained as much as 15.0 percent crude protein and 1.42 percent potassium nitrate (KNO_3). Silage made from the drought-injured corn contained 15.9 percent crude protein on the dry basis and 2.2 percent KNO_3. Pfander *et al.* (12) found that drought-injured corn silage contained as much as 11.8 percent crude protein on the dry basis. Plants are considered potentially dangerous to cattle when they contain more than 1.5 percent nitrate, as KNO_3, on the dry basis. Under normal conditions there is no danger from nitrate poisoning when corn silage is fed. Nitrate poisoning in cattle was reviewed recently by Kingsbury (8).

The ether extract values reported in this investigation ranged from 0.73 to 1.32 percent (average 1.00), or from 2.64 to 4.62 percent (average 3.44) on the dry basis. This latter value is slightly higher than the average values of 2.9, 2.9 and 3.0 percent, reported by Morrison, Schneider, and NAS-NRC, respectively. If 3.44 is multiplied by 73.7 percent and the resulting value multiplied by 2.25 for use in the calculation for TDN, the resulting TDN value may be too high.

The crude fiber content of the corn silages varied from 4.88 to 9.72 percent (average 6.21) or from 17.2 to 31.6 percent (average 21.3) on the dry basis. The latter value is lower than the average values of 24.3, 26.9, and 25.1 percent reported by Morrison, Schneider, and NAS-NRC, respectively. The NAS-NRC values ranged from 19.0 to 42.1 percent.

The nitrogen-free extract (NFE) values varied from 12.8 to 20.0 percent (average 17.7) or from 41.6 to 65.7 percent (average 60.8) on the dry basis. The NAS-NRC values ranged from 41.4 to 81.9 percent (average 57.6) on the dry basis, whereas Morrison and Schneider reported average values of 58.7 and 56.3 percent, respectively. In 14 of the 17 consecutive years, the NFE values ranged from 60.7 to 65.7, whereas the three lowest NFE values (less than 60.0 percent) occurred in the years in which the average rainfall was one inch or less in July.

Mineral and Carotene Analyses

The values obtained on the mineral and carotene content of the corn silages are shown in Table 2 and are presented on the wet basis. For comparative purposes with data published by Morrison, Schneider, and NAS-NRC, the average values are presented on both the wet

and dry basis. The calcium content varied from 0.052 to 0.107 percent (average 0.075) or from 0.18 to 0.33 percent (average 0.26) on the dry basis. The NAS-NRC values ranged from 0.08 to 0.81 percent (average 0.33) on the dry basis, whereas Morrison's average value on the wet basis was 0.10 percent and 0.36 percent on the dry basis. Using the average value of 0.075 percent, a 1,200-pound cow consuming 60 pounds of corn silage per day would receive 20.4 grams of calcium. The calcium requirement for maintenance is 10.0 grams which leaves 10.4 grams for milk production or the production of 10.4 pounds of milk per day (10). When a legume hay or mixtures of hay containing legumes is fed with corn silage, a calcium supplement is not needed, but when low calcium roughages are fed, such as most grasses, a calcium supplement is recommended.

The phosphorus content of the corn silages varied from 0.052 to 0.109 percent (average 0.071) or from 0.19 to 0.34 percent (average 0.24) on the dry basis. The NAS-NRC values varied from 0.06 to 0.55 (average 0.23) on the dry basis, whereas Morrison's average value on the wet basis was 0.07 and 0.25 percent on the dry basis. A 1,200-pound cow receiving 60 pounds of corn silage per day which contained 0.071 percent phosphorus would receive 19.3 grams of phosphorus. The requirement for maintenance is 10.0 grams per day which leaves 9.3 grams for milk production or the production of 13.3 pounds of milk (10). Corn silage is usually fed with a grain mixture which contains sufficient phosphorus to meet the needs for liberal milk production.

The average values obtained for the magnesium and potassium content of corn silage are in good agreement with those published by Morrison and NAS-NRC. The values obtained for the minor elements, iron, copper, cobalt, and manganese, are comparable in some respects to those published by Morrison and the NAS-NRC, but too few values are available in the literature to draw definite conclusions.

The carotene values presented in Table 2 varied from 2.1 to 10.8 (p.p.m.) or milligrams per kilogram (average 5.3) or from 6.4 to 38.7 p.p.m. (average 18.2) on the dry basis. This latter value is much lower than that reported by Morrison (46.4) or by the NAS-NRC (45.5). Converse and Wiseman (3) determined the carotene content of 30 samples of corn silage and found a variation from 4 to 156 milligrams per kilogram (average 50.0) on the dry basis. They also showed that the amount of carotene varied with the stage of maturity, i.e., undented ears in 100 percent milk stage contained 138 milligrams per kilogram on the dry basis, but only 32 milligrams when the ears were dented. Ears

which were dented and exposed to light frost before made into silage only contained 4 milligrams of carotene.

Digestion Coefficients

A total of 27 dairy cows were used during the 8 years to determine the coefficients of digestibility of the corn silages. Table 3 shows that the coefficients for dry matter and organic matter varied from 61.5 to 74.7 (average 67.8) compared to 67 for cattle and 66 for sheep as reported by Schneider. The coefficients for protein ranged from 43.9 to 62.9 (average 52.8) compared to a value of 54 as reported by Morrison and 45 according to Schneider.

The chief sources of productive energy in the corn plant are the crude fiber and nitrogen-free extract fractions since large quantities of each are present and because of their relatively high digestibility. The crude fiber coefficients varied from 40.9 to 68.8 (average 60.8). This value is slightly lower than that reported by Morrison (65) and by Schneider (64). It is of interest, however, that in 19 of the 27 digestion trials, the coefficients were above 60 (average 64). The nitrogen-free extract coefficients varied from 68.9 to 78.7 (average 73.4). This average value compares favorably with the value reported by Morrison (70) and by Schneider (69) for cattle. The TDN coefficients varied from 62.0 to 75.6 (average 68.6), which average value is slightly higher than reported by Morrison (66) and by Schneider (64) for cattle. The productive energy value of corn silage is actually higher than the TDN content would indicate because of the corn grain present in the silage. Previous work has shown the high milk-producing power of corn silage compared to hay (4, 6 and 7).

The digestible crude protein content of the silages varied from 3.9 to 8.3 (average 5.1). If the 1946 digestible protein values were omitted from the average, the average value would be reduced to 4.7, which value is higher than that reported by Morrison (4.3) and by Schneider (3.4). As stated previously, the higher values found for digestible protein in the 1946 silage may have been associated with drought conditions during the growing season. Nitrates were not determined, but it is postulated that there was an unusually high accumulation of nitrates in the 1941 and 1946 corn silages.

The effect of the plane of nutrition has been investigated by Watson *et al.* (15) who fed 17.6, 30.8, 44.0, and *ad libitum* pounds of corn silage per day per steer. The coefficients of digestibility were 70.4, 68.1, 65.9, and 63.4, respectively, for the four levels of corn silage

intake. As shown in Table 3, the daily intake of dry corn silage varied from 1.19 to 1.82 pounds per 100 pounds of body weight (average 1.47). On the wet basis, the silage intake varied from 31 to 49 pounds per day.

SUMMARY

The average percentage composition of corn silages over a 17-year period from 1940 to 1956, inclusive, were: dry matter, 29.1; ash, 1.45; crude protein, 2.74; ether extract, 1.00; crude fiber, 6.21; NFE, 17.7; calcium, 0.075; phosphorus, 0.071; magnesium, 0.077; potassium, 0.34; and iron, copper, cobalt, manganese, and carotene as milligrams per kilogram (p.p.m.) 63, 4, 0.03, 8, and 5.3 respectively. The average pH of the silage was 4.0.

The average coefficients of digestibility for 8 of the silages were: dry matter, 66.8; organic matter, 67.8; and NFE, 73.4 percent. The mean digestible protein and TDN values were 5.1 and 68.6 percent, respectively.

The need for supplemental protein, calcium, and carotene (provitamin A) is indicated when corn silage makes up all or a large part of the total ration.

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SOME NORMS OF SPERM OUTPUT FOR DAIRY AND BEEF BULLS[1]

By HAROLD D. HAFS and ROBERT C. KNISELY

Department of Dairy

Before performing an experiment, the researcher should decide upon the number of replications needed for his purposes. In the past, this decision has been made largely arbitrarily, but statistical methods now exist to improve the chances of making an adequate decision, provided that a relatively large quantity of prior data is available. The prior data may be used to estimate the magnitude of the error variance, which may then be used to calculate the number of replicates necessary to detect a specified difference between treatments at a specified level of significance (P_I), and with a specified probability [$(1 - P_{II})$ = the power of the test] of detecting the difference.

Calculations of the power of possible analysis of variance F tests have been made for sperm output criteria for the bulls in four large bull studs.[2] That report indicated the results differ appreciably from one bull stud to another. Consequently, the primary objective of this study was to estimate some of the variance components for some sperm output criteria and to use these variances to estimate the numbers of replications needed for future sperm output experiments with the bulls in the Michigan Artificial Breeders Cooperative.

A second intent of the present study was to determine the efficiency of the electrical ejaculation procedure and the efficiency of the practice of taking second ejaculates from dairy and from beef bulls under routine bull stud conditions.

EXPERIMENTAL PROCEDURE

The data consisted of the records of sperm output from the bulls in the Michigan Artificial Breeders Cooperative during the 52-week

[1]The authors wish to express appreciation to the Michigan Artificial Breeders Cooperative, East Lansing, for making the data available.

[2]Hafs, H. D., R. W. Bratton, C. R. Henderson, and R. H. Foote (1958). Estimation of some variance components of bovine semen criteria and their use in the design of experiments. Jour. Dairy Sci. 41: 96.

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period starting December 21, 1957. The percent of motile sperm in the fresh unextended semen was estimated after dilution in 0.9 percent sodium chloride and the concentration of sperm in the semen was measured with a Cenco photelometer.[3] These procedures for semen examination were essentially those of Willett and Salisbury.[4]

The component of variance analyses, one for each of five sperm output criteria, considered the six sources of variation shown in Table 1. The season and the breed sources were considered to be fixed and factorial, the animal (bull) source to be random and nested within breed, and the ejaculate source to be random and nested within bull-breed-season. The following mixed linear model was considered to be appropriate for these data:

$X_{hijk} = \mu + s_k + b_j + sb_{jk} + a{:}b_{ij} + sa{:}b_{ijk} + e{:}abs_{hijk}$, where X_{hijk} is the value for the h^{th} ejaculate, from the i^{th} animal, in the j^{th} breed, and in the k^{th} season. In this model, μ is the mean of the population and the other components of the model were assumed to be uncorrelated variables with means of zero and variances of σ^2_s, σ^2_b, σ^2_{sb}, $\sigma^2_{a:b}$, $\sigma^2_{sa:b}$, and $\sigma^2_{e:abs}$, respectively. The expectations of the mean squares and the coefficients of the components of these expectations, shown in Table 1, were determined by Henderson's procedures.[5,6]

TABLE 1—Measured sources of variation and the expectations of their mean squares

Source of variation		Expectations of mean squares
Season	S	$\sigma^2_{e:abs} + 7\ \sigma^2_{sa:b} + 175\ \sigma^2_s$
Breed	B	$\sigma^2_{e:abs} + 28\ \sigma^2_{a:b} + 117\ \sigma^2_b$
Interaction	SB	$\sigma^2_{e:abs} + 7\ \sigma^2_{sa:b} + 29\ \sigma^2_{sb}$
Animal (bull)	A:B	$\sigma^2_{e:abs} + 28\ \sigma^2_{a:b}$
Interaction	SA:B	$\sigma^2_{e:abs} + 7\ \sigma^2_{sa:b}$
Ejaculate	E:ABS	$\sigma^2_{e:abs}$

The extensiveness of the data permitted selection of bulls and ejaculates to avoid the computational labor of an unbalanced component of variance analysis. To qualify for use in this analysis, each bull had at least one ejaculate in each consecutive 3-week period during the 52 weeks of the study, and at least seven ejaculates in each of the

[3]Available from Central Scientific Co., Chicago, Illinois.

[4]Willett, E. L., and G. W. Salisbury (1942). The effect of various diluters, cooling rates, temperatures of storage, and some other factors, on the livability of spermatozoa in stored samples of bull semen. Cornell Univ. Agr. Expt. Sta., Memoir 249.

[5]Henderson, C. R. (1953). Estimation of variance and covariance components. Biometrics. 9:226.

[6]Henderson, C. R. (1955). The design and analysis of animal husbandry experiments. Dept. of Animal Husbandry, Cornell University. (Mimeo.).

four 13-week seasons of the year. If a bull had more than seven ejaculates for a season, the excess, which was to be discarded, was chosen at random.

RESULTS AND DISCUSSION

Twenty-six dairy and eight beef bulls had from 2 to 48 second ejaculates per bull with a total of 370 from the dairy bulls and 93 from the beef bulls. To assess the sperm output in second ejaculates, each second ejaculate was compared with the first ejaculate taken on the same day and every first ejaculate not followed by a second ejaculate was eliminated. The first and second ejaculates were averaged for each bull and these values were then used to obtain the averages in Table 2, which indicate that the average second ejaculate contains a number of sperm not very different from that in the average first ejaculate ($P > .25$). However, the average of 6.6 billion motile sperm for first ejaculates shown in Table 2 is considerably less than the 10.4 billion for all first ejaculates shown in Table 4. This probably reflects the fact that a second ejaculate is routinely taken only when the first ejaculate contains an insufficient number of sperm. Nevertheless, the average of 7.1 billion motile sperm per second ejaculate for dairy bulls (Table 2) is about 70 percent of the average of 10.4 billion for all first ejaculates (Table 4), and this fact indicates that the procedure of taking second ejaculates is justifiable in terms of total sperm output.

TABLE 2—Averages of first and second ejaculates for five sperm output criteria

Criterion	Dairy bulls		Beef bulls	
	First Ejac.	Second Ejac.	First Ejac.	Second Ejac.
Volume of semen (ml)	5.4	7.0	4.4	5.6
Percent of motile sperm	73	73	68	70
Sperm/ml. of semen (x 10^9)	1.7	1.4	1.7	1.4
Sperm/ejac. (x 10^9)	9.1	9.7	7.0	7.8
Motile sperm/ejac. (x 10^9)	6.6	7.1	4.6	5.5

Five dairy and two beef bulls were ejaculated by means of electroejaculation and by means of an artificial vagina. The average of these seven bulls for each method of ejaculation and for each of the five sperm output criteria is shown in Table 3. One may conclude that

TABLE 3—Averages of ejaculates taken by electrical stimulation and by artificial vagina for five sperm output criteria

Criterion	Artificial vagina ejaculates	Electrical ejaculates
Number of ejaculates	241	70
Volume of semen (ml.)	6.2	10.0
Percent of motile sperm	72	68
Sperm/ml. of semen (x 10^9)	2.2	1.4
Sperm/ejaculate (x 10^9)	13.7	14.5
Motile sperm/ejaculate (x 10^9)	9.9	10.1

electro-ejaculation results in an ejaculate with a larger volume, but with a lower sperm concentration than ejaculation with an artificial vagina ($P<.01$). The 10.1 billion motile sperm per electro-ejaculate is essentially equivalent to the 9.9 billion for ejaculates taken with an artificial vagina ($P>.50$).

Seventeen Holstein, three Guernsey, two Jersey, and three Brown Swiss bulls qualified for the component of variance analyses, giving a total of 700 ejaculates in this study. The means, overall standard deviations, and coefficients of variation for each of the five sperm output criteria are shown in Table 4. These values are in good agreement with comparable data from four other large bull studs.[2]

Differences among breeds, among seasons, and among the season by breed interactions were insignificant ($P>.05$) in the analysis of variance for each of the five sperm output criteria. Bulls, on the other hand, differed significantly ($P<.001$) in each of the five analyses. The interaction between seasons and bulls was significant ($P<.01$) in all analyses except the one for motility, indicating that certain bulls are sensitive to seasonal changes but that this sensitivity differs among bulls.

TABLE 4—Ejaculate averages, standard deviations, and coefficients of variation for the five sperm output criteria

Criterion	Average	Standard deviation	Coefficient of variation
Volume of semen (ml)	7.5	2.5	33
Percent of motile sperm	73	3.1	4
Sperm/ml. of semen (x 10^9)	1.90	0.44	23
Sperm/ejaculate (x 10^9)	14.3	5.9	42
Motile sperm/ejaculate (x 10^9)	10.4	4.3	41

The values obtained for the components of variance are shown in Table 5, where it may be seen that the combined bull ($\hat{\sigma}^2_{a:b}$) and ejaculate ($\hat{\sigma}^2_{e:abs}$) components account for at least 90 percent of the total variation in each criterion. Consequently, these two sources of variation are of primary importance in the design of future sperm output experiments. Also, one finds many negative values among the estimates of σ^2_s, σ^2_b, and σ^2_{sb}. But since negative variances are impossible, these negative values are considered to be estimates of parameters which are very close to or equal to zero.

TABLE 5—Estimates of the variance components for the five sperm output criteria

Component of variance	Volume of ejaculate	Percent of motile sperm	Sperm per ml. of semen	Sperm per ejaculate	Motile sperm per ejaculate
$\hat{\sigma}^2_s$	0.00	0.08	0.00	−0.05	−0.02
$\hat{\sigma}^2_b$	−0.08	−0.13	−0.01	−2.68	−1.37
$\hat{\sigma}^2_{sb}$	−0.14	−0.19	0.00	−0.63	−0.29
$\hat{\sigma}^2_{a:b}$	3.30	1.62	0.07	16.91	8.58
$\hat{\sigma}^2_{sa:b}$	0.35	0.27	0.02	2.36	1.30
$\hat{\sigma}^2_{e:abs}$	2.82	7.85	0.11	19.40	10.27
$\hat{\sigma}^2_{total}$	6.25	9.50	0.19	35.31	18.47

To calculate the power of the test for a two-treatment experiment on the basis of the data in Table 4, Tang's Φ was computed as follows:

$$\Phi = \frac{d}{2\sigma_{\bar{x}}},$$

where d is the treatment difference to be detected and $\sigma_{\bar{x}}$ is the standard deviation of a treatment mean. Because $\hat{\sigma}^2_{a:b}$ and $\hat{\sigma}^2_{e:abs}$ accounted for at least 90 percent of the total variance (see Table 4), $\sigma_{\bar{x}}$ was estimated from the following formula:

$$\hat{\sigma}_{\bar{x}} = \sqrt{\frac{\hat{\sigma}^2_{a:b}}{n_a} + \frac{\hat{\sigma}^2_{e:abs}}{(n_a)(n_e)}},$$

where $\hat{\sigma}^2_{a:b}$ is the bull variance, $\hat{\sigma}^2_{e:abs}$ is the ejaculate variance, n_a is the number of bulls per treatment, and n_e is the number of ejaculates per bull.

Having Φ, one may find P_{II} from Tang's tables of Φ.[7] Subtracting P_{II} from one gives the power of the test, that is, the probability of detecting a treatment difference as large as or larger than that used in the calculation of Φ.

The power of the analysis of variance F test was estimated for some possible two-treatment experiments with varying numbers of bulls per treatment and ejaculates per bull. These values are summarized for each of the five sperm output criteria in Table 6. It is

[7] Tang, P. C. (1938). The power function of the analysis of variance tests with tables and illustrations of their use. Statistical Research Memoirs. 2:126.

TABLE 6—Percent chance of detecting a treatment difference of 50% or 25% of the mean at the 5% level of significance with varying numbers of bulls per treatment and ejaculates per bull

Criteria	Number of bulls per treatment	Treatment difference to be detected							
		50% of the mean				25% of the mean			
		Number of ejaculates per bull per treatment							
		5	10	20	50	5	10	20	50
Volume of ejaculate	2	20	22	22	22	<14	<14	<14	<14
	5	74	77	78	80	28	29	30	30
	10	98	99	99	99	52	55	56	57
	20	99	99	99	99	82	85	86	87
Percent motile sperm	2	99	99	99	99	99	99	99	99
	5	99	99	99	99	99	99	99	99
	10	99	99	99	99	99	99	99	99
	20	99	99	99	99	99	99	99	99
Concentration of sperm per ml.	2	40	42	45	45	15	17	18	18
	5	97	98	99	99	56	62	64	66
	10	99	99	99	99	89	92	93	94
	20	99	99	99	99	99	99	99	99
Total sperm per ejaculate	2	17	17	18	18	<14	<14	<14	<14
	5	58	62	65	66	<24	<24	<24	<24
	10	91	93	94	94	39	42	43	44
	20	99	99	99	99	66	70	73	75
Motile sperm per ejaculate	2	17	18	18	19	<14	<14	<14	<14
	5	59	64	66	68	<24	<24	<24	<24
	10	92	94	95	95	40	43	45	46
	20	99	99	99	99	68	72	75	76

apparent that 10 bulls per treatment and 5 or 10 ejaculates per bull provide relatively good chances (>91 percent) of detecting a difference of 50 percent of the mean. On the other hand, one should have at least 20 bulls per treatment and at least 10 ejaculates per bull to have a reasonable chance (72 percent) of detecting a difference of 25 percent of the mean of motile sperm per ejaculate. The values in Table 6 also illustrate the futility in performing many possible experiments, because the chances of detecting the treatment differences are unacceptably small.

There are four alternatives for increasing the chances of detecting a treatment difference. They include increasing the level of significance (e.g., using the 10 percent rather than the 5 percent level of significance), attempting to detect a larger difference, using more replicates per treatment, and/or reducing the magnitude of the error variance. The final choice of each of these four factors is dependent upon the resources available and upon the value of the detectable difference.

SUMMARY

Semen production records for second ejaculates and for ejaculates taken by electrical stimulation were compared with first ejaculates routinely taken by artificial vagina from the bulls at Michigan Artificial Breeders Cooperative. Second ejaculates from 26 dairy and 8 beef bulls averaged 7.1 and 5.5 billion motile sperm per ejaculate, respectively, values that are about 70 percent of that normally expected for first ejaculates. Ejaculation of seven bulls by electrical stimulation resulted in an average of 10.1 billion motile sperm per ejaculate.

Semen production records of 25 dairy bulls were used to estimate the bull, ejaculate, breed, season, and interaction variance components of five semen output criteria. The means and standard deviations for the five criteria were: ml. of semen per ejaculate, 7.5 ± 2.5; percent motile sperm, 73 ± 3.1; billions of sperm per ml. of semen, 1.90 ± 0.44; billions of sperm per ejaculate, 14.3 ± 5.9; and billions of motile sperm per ejaculate, 10.4 ± 4.3. The bull and ejaculate components of variance accounted for more than 90 percent of the total variation in each criterion and consequently were used to estimate the power of the test by Tang's method. These estimates indicated that to have a 75 percent chance of detecting a treatment differ-

ence of 25 percent of the mean of motile sperm per ejaculate at the 5 percent level of significance would require about 20 bulls per treatment and 20 ejaculates per bull. Ten bulls per treatment with 5 ejaculates per bull would give about a 92 percent chance of detecting a difference of 50 percent of the mean at the 5 percent level of significance.

FLAVOR QUALITY OF MILK FROM FARM BULK TANKS

By J. M. JENSEN

Department of Food Science

Dairy plant operators are vitally interested in the flavor quality of milk, its intensity, and kind of off flavor. Milk purchased in cans is examined daily for flavor quality by a competent grader. Off quality milk is returned to its producer and a dairy plant fieldman calls to help correct the problem. The bulk tank hauler is made responsible for the quality of milk he picks up from bulk tanks. A number of handicaps confront him in this task – some of which include very cold milk, conflicting odors from surroundings, and sundry disturbances. This study is reported in order to show the flavor quality encountered with bulk tank and modern production methods.

Flavor studies were made on milk received from bulk tank shipments by a local dairy purchasing only Grade A milk from approximately 110 producers. Flavor examinations were made during a period of 20 months; one sample graded monthly per producer (eight samples) from April through December in 1958; two samples were graded monthly during 1959; and one sample monthly per producer from January 1 through July 1960. On designated days, milk haulers gathered samples from all producers, four ounces in eight-ounce glass milk bottles. The milk was pasteurized in these containers in a water bath at 145°F. for 30 minutes soon after arriving at the dairy. Following pasteurization, the milk was placed in a 38°F. milk storage cooler and held approximately 20 hours, then tempered to 60°F. just before being examined for flavor quality.

The milk was critically examined by an expert milk judge, in accordance with prescribed procedures.[1]

[1]Nelson, J. A. and G. M. Trout, (1951). *Judging Dairy Products.* 3rd Ed. 480 pp. Olsen Pub. Co., Milwaukee.

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Flavor score	Grade class
40	Excellent
39–39.5	Very good—very slight off flavor
37–38	Good—distinct off flavor
35–36	Fair—pronounced off flavor
30–34	Poor—strong off flavor

A mimeograph report of all milk scores with criticisms indicated were sent to producers soon after being scored. Producers were made aware of only their own score, which was underscored or encircled.

There were several reasons for pasteurizing the samples for scoring: (1) the milk was made safe for tasting, leaving no sense of repugnance in the mind of the milk judge; (2) the raw milk taste was destroyed; (3) the flavors otherwise present were "fixed" by pasteurization, assuring that flavors which were of bacterial origin or rancid were there before the milk was pasteurized.

A number of producers used loose housing. The flavor scores of milk from 15 loose-housed herds were compared with those from 89 housed in stanchion barns.

Scoring Results of 1958

During 1958, 1.017 samples were scored from April through December. These may be considered as preliminary scorings, during which time details of scoring procedures were established and producers became adjusted to having their milk flavor quality reported to them. Emphasis was placed on finding milk of 36-35 and 34-30 score as a means of most effectively improving the over-all flavor quality through fieldman contact with those producers. Perhaps insufficient discrimination was made of milk in the upper scores to positively designate samples as being 40 or 39 score. Table 1, therefore, shows the monthly scores of milk with 40 and 39 score samples totaled.

The results secured were in line with previous flavor studies reported by Trout[2] of milk shipped in cans and graded on the receiving platform. In the earlier study, 44.9 percent of the milk was found "clean and pleasant." The tabulated scores indicate clearly the number of producers in the various flavor quality groups and

[2]Trout, G. M. (1939). Distribution of flavors of milk at the receiving platform. Mich. Agr. Expt. Sta. Quart. Bul. 21 (3); 228-230.

particularly those needing to be worked with to correct practices resulting in scores from 36 downward. Those with 34-30 score averaged 5.4 percent and those with 36-35, 16 percent.

TABLE 1—Distribution of flavor scores of milk, April through December 1958, recorded as percent of samples

Score	Months									Average
	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
40-39.....	40.5	50.0	58.6	58.1	33.5	43.6	24.3	44.5	45.0	43.3
38-37.....	39.0	26.7	24.1	19.6	31.0	40.9	60.3	34.5	43.2	35.3
36-35.....	23.7	16.4	13.8	15.2	24.8	11.8	11.7	14.5	19.9	16.0
34-30.....	6.9	6.9	3.4	7.1	10.6	3.6	1.8	6.4	1.8	5.4
Average score....	37.5	37.9	38.4	38.2	37.4	38.2	37.8	37.8	38.2	37.9(*a*)

(*a*) Average of averages.

Scoring Results of 1959

During 1959, the number of scoring periods was increased to two per month, excepting two months as described below, with anticipation of stimulating initiative in producers to improve the flavor quality of their milk. In a sense, this change was motivated by economy and with the hope of reducing the number of calls by the fieldman. A disturbance developed during August and September because of a producer strike situation. Only one sample was taken per producer during these months.

Extreme care was exercised in the scoring of the samples. The routine was now well established and producers were accustomed to receiving reports about flavor score. Thus, the result should reliably reflect established practices relating to flavor quality.

The percentage of samples in the various flavor scoring classes is shown in Table 2.

Data from this table, for 1959, are remarkably like those shown in Table 1, for 1958. A very small decrease occurred in the percentage of samples of 40-39 score, from 43.3 to 42.4; while the percentage of 36-30 score samples decreased from that of 21.4 percent in 1958 to 20.7 percent in 1959. These small changes, showing a very small lowering of quality in 1959 over 1958, are also supported by a change in the net average score for the two years, 37.9 in 1958 and 37.8 in 1959.

TABLE 2—Summary of flavor scores for 1959-1960 in percent of samples

Flavor score	Months 1959 (representing 2,286 samples)												Avg.
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
40-39	40	50	55	35	39	44	46	33	38	32	35	38	42.4
38-37	34	33	28	36	38	34	37	47	42	45	44	46	36.9
36-35	24	12	12	13	13	15	11	16	18	15	15	9	14.4
34-30	2	5	5	10	10	7	6	5	2	8	6	7	6.3
Avg.	37.7	38.1	37.9	37.8	37.6	37.7	37.9	37.6	37.9	37.6	37.6	37.8	37.8

	1960 (representing 1,017 samples)						
40-39	47	50	25	16	24	18	20.5
38-37	49	39	43	56	48	50	49.5
36-35	8	17	22	18	19	26	18
34-30	6	5	10	14	9	6	12
Avg.	38.1	37.9	37.7	36.8	37.1	37.0	37.0

Scoring Results of 1960

The scoring results of 1960 are also shown in Table 2 and include data through July. Grading returned to a once-a-month frequency. The pattern of flavor quality remained as for the previous year through February, from where a decisive lowering of flavor quality occurred. The scores for milk from March through June averaged 0.8 points less per sample during 1960 than in 1959. A reduction of 22.5 percent occurred in the 40-39 score samples, while the 36-30 group averaged 7 percent higher than the previous year.

Strong feed flavors from silage caused many low flavor scores during the month of March. From April, through June, strong grass, rye, and alfalfa flavors occurred in many samples of milk. Weather conditions prevailed that kept pastures lush continuously.

Only 7 percent produced milk of sufficiently consistent high

TABLE 3—Distribution of yearly average producer-flavor scores(a)

Milk flavor score range	Number of producers
40-39	7
38-37	83
36-35	10
34-30	0

(a) The average milk flavor score per producer was calculated and distributed percentagewise.

flavor quality to have an average score of 40-39 during 1959. Among these, one producer's milk averaging 39.8. This producer had 18 samples of 40 score, four with 39. A majority, 83 percent, of samples averaged 38-37 score; while 10 percent had average scores ranging from 36-35.

Nature of Flavors Found in Milk

Knowledge of the kind of flavor defects in milk is equally as valuable as the intensity of defects. When the kind and source of defect is known, correction can be made – usually quite rapidly. Table 4 is a summary of the variety of flavors found in the 2,286 producer samples of this study.

Of 2,286 samples scored, 513 or 22.44 percent possessed no off flavor. This was important because of showing that producing milk free of defect was an accomplishment of a large number of producers, 101 of 105 milk samples tested and recorded here. The one outstanding producer referred to above, with 18 of 22 samples scoring 40, should be emulated by many others. Having one producer constantly producing top score milk gives a dairy an excellent example for others to follow.

The most prevalent flavor defect encountered was of feed origin found in 72.7 percent of the samples and in milk of all the producers.

TABLE 4—Nature and distribution of flavors found in bulk tank milk

Flavor	Producers involved		Incidence	
	Number	Percent	Number	Percent
No defect				
40 score	101	96.19	513	22.44
Defects				
Feed	105	100.00	1,661	72.66
Unclean	16	15.24	22	.96
Rancid	14	13.33	41	1.79
Utensil	7	6.67	8	.35
Hallogen(*a*)	7	6.67	10	.44
Salty	6	5.71	10	.44
Oxidized	5	4.76	8	.35
Musty	4	3.81	4	.17
Malty	4	3.81	4	.17
Flat	3	2.86	3	.13
Cowy	2	1.90	2	.08

(*a*) Bromine, chlorine, iodine.

The flavor scores given to feed flavor ranged from 39.5 to 33.0. A total of 77 feed flavored samples were found in milk which was in the 34-30 score range and 296 in the 36-35 range. When feed flavor is present sufficiently to cause 36-33 score milk, producers can be assumed to apply very faulty feeding of roughage. Highest incidence of strong feed flavor occurred when cows were on early pasture.

Unclean flavor designated milk possessing unpleasing flavors with no definitely determined origin. There was suggestion of protein decomposition in some, borderline rancidity in others, and some left suspicion of mastitis. Only 22 samples by 16 producers were found, showing there were at least six repeat incidents.

Rancidity was found in 41 samples from 14 different producers during 1959, thereby showing that repitition of the flavor in milk of the same producers occurred to a fairly high degree. Because rancidity is recognized as occurring more frequently in milk from pipeline than nonpipeline milkers, Table 5 was prepared to show incidence or rancidity which occurred from the samples studied.

TABLE 5—Distribution of rancid flavors from pipeline and nonpipeline milkers

	Pipeline	Nonpipeline
Number	12	92
Incidence of rancidity		
Producers	3	17
Samples	17	28
Incident ratio	1:5.7	1:1.7

Of 104 producers from which the data of Table 5 were obtained, 12 had pipeline milkers and 92 were of nonpipeline varieties. The incidence of rancidity occurred among 3, or 25 percent, of the pipeline milkers, where 17 samples were found rancid. Of 92 producers using nonpipeline milkers, 17 producers, or 18.4 percent, experienced trouble with rancidity, which occurred in 28 samples. These data, therefore, support the concept that rancidity is more commonly found when pipeline milking is used than otherwise. However, 75 percent of the pipeline milking systems used caused no rancidity; also, rancidity occurred in nonpipeline milk in 28 occurrences.

Comparison of Flavor Quality Level from Year to Year

The flavor scores for 1958, 1959, and 1960 were compared to observe possible trends in milk flavor quality resulting with bulk tank production. Such a comparison was made using data from April through December 1958 and 1959 and from January through July for the years 1959 and 1960. These months were used inasmuch as the 1958 data were begun in April and the 1960 data were concluded with the July scoring. The difference in the average monthly scores for milk shown by Table 6 point to a small drop in scores during seven months and a small increase during only two months during 1959 over 1958.

There was a net decrease averaging 0.2 points in score during this period. Similarly, losses in score values occurred during six of the seven months of 1960 over 1959. The average loss during this seven-month comparison was 0.5 points, much greater than during the 1958-1959 period. A plausible reason for the greater loss in score value may be attributed to an extended period of lush pasture during the spring of 1960. Perhaps also the number of flavor scorings and limitation of follow-up field visits may have contributed to decreased attention on the part of producers to the flavor quality.

From these data showing a decrease in scores during two successive years, evidence in this study showed that a lowering of flavor quality may occur with the use of bulk tanks. The lowering of flavor quality became greater when the frequency of flavor inspection

TABLE 6—Comparison of monthly average scores

Year	Months									Average
	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1958.....	37.5	37.9	38.4	38.2	37.4	38.2	37.8	37.8	38.2	37.9
1959.....	37.8	37.6	37.7	38.0	37.6	37.9	37.6	37.6	37.8	37.7
Difference.....	+0.3	−0.3	−0.7	−0.2	+0.2	−0.3	−0.2	−0.2	−0.4	−0.2

	Jan.	Feb.	Mar.	April	May	June	July	Average
1959.....	37.7	38.1	37.9	37.8	37.6	37.7	38.0	37.8
1960.....	38.1	37.9	37.4	36.8	37.1	37.0	37.0	37.3
Difference.....	+0.4	−0.2	−0.5	−1.0	−0.5	−0.7	−1.0	−0.5

decreased. A remote possibility existed that the strike situation may have influenced neglect of flavor quality. No real support can be attributed to this possibility, however, since the drop in score during August and September was no lower than for the preceding months.

Comparison of Flavor of Milk with Respect to Housing

A segregation was made of milk scores from herds kept in stanchion barns vs. those kept with loose housing but excluding all except feed and no off flavored milk. The results shown in Table 7 favored loose housing from the standpoint of providing better conditions for feeding to minimize the effect of feed flavor.

TABLE 7—Comparison of stanchion barn and loose housing on flavor score of milk

	Loose housing	Stanchion barn
Producers	15	89
Milk score (average)	38.5	37.9
Score distribution (%)		
40-39	48.6	43.1
38-37	34.8	38.6
36-35	12.1	14.4
34-30	4.5	3.9

Ability of Haulers to Determine Quality

Bulk tank haulers were required to inspect milk for flavor quality before loading. In view of this, it was significant that strongly off flavored milk, including rancid milk, was received by the haulers. It may, therefore, be concluded that discrimination of milk flavor quality by milk haulers may not be relied upon.

Conclusion and Discussion

Bulk tank milk may be adequately inspected for flavor quality by grading samples in the plant laboratory. Samples should be pasteurized immediately on arriving in order to arrest rancidly and bacterial development as well as making the milk safe for tasting. Judgment by taste and smell as practiced in this study is believed more reliable than by smell only.

Reports of flavor inspection sent to producers monthly or bimonthly directed producer and hauler interest to problems of flavor

quality. Conscientious producers made real efforts to correct faulty management practices and make improvement. The indifferent ones were not affected. While some lowering in flavor quality occurred from 1958 to 1959 and 1960, during the time the laboratory inspections were in effect, a considerably greater lowering in flavor quality might have resulted in the absence of such inspection. A significantly greater drop off in quality occurred as bimonthly inspection was replaced by monthly inspection.

Fieldman follow-up was believed to be of great importance in securing correction of off flavor. During 1958 a regularly employed fieldman was engaged. He was replaced by a part-time fieldman who also was in charge of laboratory control and part-time plant supervision. His effectiveness was unquestionably depreciated by inability to make the number of farm calls needed to correct conditions causing 36-30 score milk.

There was encouragement in the number of producers consistently producing milk of the finest flavor quality, 40 score, 22.4 percent. Milk of high flavor score was commonly produced when roughage type feed was fed directly after milking either once or twice daily under either stanchion or loose housing conditions. The finest flavor quality, averaging 39.8 score, resulted with loose-housing and feeding all of the day's silage allotment directly after the morning milking.

Feed flavor was by far the most prevalent off flavor and was detected in 72.7 percent of the milk supply. The problem is well recognized but never remedied without changing habits of management. A call from the fieldman and a decision as to quality of milk that will be accepted is usually necessary for permanent correction.

Rancid flavor ranked second in incidence but was detected in only 1.8 percent of the milk purchased. The highest rate of incidence was observed with pipeline milking. Perhaps equally significant was the finding that 75 percent of pipelines did not yield rancid milk.

No incidence of rejection of milk through haulers examination occurred during the 28 months of this study. When milk was rejected by the plant, the faulty conditions were uncovered in the laboratory.

CONTROL OF RED MAPLE STUMP SPROUTS

By MAURICE W. DAY
DUNBAR FOREST EXPERIMENT STATION

RED MAPLE (*Acer rubrum* L.) has a very vigorous sprouting habit which makes it a difficult species to control in timber stand improvement work. Whenever a tree is cut, a dense clump of sprouts arises from the stump, and may reach 4 or more feet in height in one growing season. When red maple makes up even a small proportion of a stand, and some red maple is cut, its sprouting ability usually results in an increase in the component of the species. Such an increase is especially undesirable, since the sprout clump new growth is not likely to produce anything but the lowest value wood products.

When red maple is cut, good forest management makes it desirable to treat the stumps to prevent sprouting. This is best done before the sprouts first appear. There are several reasons for this, but the main one is that the stumps are easier to find and, furthermore, less material is required to treat the stumps properly. When the work cannot be done until after sprouting has occurred, the treatment takes on aspects of a combined foliage, stem, and stump spray. Several herbicides have been suggested for this purpose. This report describes the results obtained in testing several herbicides.

Procedure for Freshly-Cut Stumps

Both recently-cut stumps and others up to 10 years old were treated in this study. A total of 130 red maple was used for the tests on freshly-cut stumps. Ten or more stumps were given each treatment, and a similar group was left untreated for comparison as a control. The solution was applied to the stumps with a knapsack sprayer by wetting the entire surface above the ground to the point of runoff.

Three products were applied in fuel oil at a concentration of 12 lbs.

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ahg. (acid per hundred gallons of solution). One of the products was also applied at 6 lbs. ahg. These treatments were:

1. Twelve lbs. ahg. of a formulation containing 4 lbs. acid equivalent per gal. of 2,4,5-T as the propylene glycol butyl ether ester.
2. Six lbs. ahg. of a formulation containing 2 lbs. acid equivalent per gal. of 2,4,5-T as the propylene glycol butyl ether ester.
3. Twelve lbs. ahg. of formulation used in treatment 2.
4. Twelve lbs. ahg. of a formulation containing 4 lbs. acid equivalent of 2,4,5-T as the butoxy ethanol ester.

Results With Oil Solutions

An examination of these stumps one year after treatment showed that all products were completely effective in preventing sprouting. The fact that formulation No. 2 was effective at half-strength indicates that concentrations of less than 12 lbs. ahg. might be satisfactory with the other products also.

Water Solutions Used

Five other products were applied in a similar manner, except that water solutions were used. The treatments were:

1. Twelve lbs. ahg. of a liquid formulation containing 2 lbs. 3-amino-1,2,4,-triazole per gal.
2. Twelve lbs. ahg. of a formulation containing 1 lb. 3-amino-1,2,4-triazole plus 4 lbs. polychlorinated benzoic acid (as amine salt) per gal.
3. Twelve lbs. ahg. of a formulation containing 4 lbs. alkanolamine salt of 2,4-D per gal.
4. Twelve lbs. ahg. of a formulation containing 4 lbs. of triethylamine salt of 2,4,5-T per gal.
5. Six lbs. ahg. of a formulation containing 2 lb. propylene glycol butyl ether ester of 2,4,5-T per gal.

Results With Water Solutions

Examination one year later of the stumps given the water solution treatment showed a considerable range in effectiveness. Based on a

numerical rating system with 100 percent equal to a complete kill, the treatments as listed above rated as follows:

Formulation No.	Percent kill
1.	16
2.	76
3.	8
4.	98
5.	80

These ratings indicate that the last two formulations, and possibly Number 2, could be used in water solution to prevent sprouting. The half-strength concentration of Number 5 should be noted in evaluating its effectiveness. Since oil solutions heretofore have been considered essential for stump sprays, the results obtained with these water solutions are of particular significance.

Procedure for Older Stumps

The older stumps treated in the study were of different ages and all had established sprouts. The varying size of the sprouts affected the results obtained. However, some indications of the possibilities in this situation are evident. As with the fresh stumps, fuel oil, and water solutions were applied to different groups of older stumps. Fuel oil, applications were:

1. Sixteen lbs. ahg. of a formulation containing 4 lbs. acid equivlent per gal. of 2,4,5-T as the propylene glycol butyl ether ester.
2. Sixteen lbs. ahg. of a formulation containing 2 lbs. acid equivalent per gal. of 2,4,5-T as the propylene glycol butyl ether ester.
3. Sixteen lbs. ahg. of a formulation containing 4 lbs. acid equivalent per gal. of 2,4,5-T as the butoxy ethanol ester.

These solutions were applied as a stem and stump spray, with some inadvertent spraying of the sprout foliage as well, to groups of 10 stumps for each formulation.

Results With Oil Solutions

Examination of these stumps one year later showed that all three solutions were completely effective in killing the sprouts present, and that they prevented any new sprouting.

Water Solutions Used

For the second group of older stumps, water solutions were prepared of four products as follows:

1. Sixteen lbs. ahg. of a formulation containing 2 lbs. 3-amino-1,2,4-triazole per gal.
2. Sixteen lbs. ahg. of a formulation containing 1 lb. 3-amino-1,2,4-triazole plus 4 lbs. polychlorinated benzoic acid (as amine salt) per gal.
3. Sixteen lbs. ahg. of a formulation containing 4 lbs. of triethylamine salt of 2,4,5-T per gal.
4. Sixteen lbs. ahg. of a formulation containing 2 lbs. per gal. of propylene glycol butyl ether ester of 2,4,5-T per gal.

All solutions were applied as a stump and stem spray from ground line to a height of 16 inches on groups of 10 stumps for each solution. Spray was applied when the bark was dry and soaked up the solution.

Results With Water Solutions

A year later these stumps showed variable results. Using the same numerical rating system that was applied to the fresh stumps, effectiveness was judged to be as follows:

Formulation No.	Percent kill
1.	26
2.	82
3.	50
4.	64

The effectivenes of the water solutions varied with the size of the sprouts. Where the sprout diameter was less than 1 inch at the base, they were usually killed. This was especially so with solutions 3 and 4. In general, however, the results were much inferior to those obtained with the oil solutions.

Discussion

The treatments using the various products in oil solutions did not show marked differences in effectiveness when used at the concentrations indicated and in the manner described. All products were effective in preventing sprouting from new stumps, or in killing established sprouts. Treatment of new stumps was preferred, because of the

greater ease in working, and the smaller amounts of solution required for treatment.

When water solutions were used, results generally were not as satisfactory as with oil solutions. However, when applied to new stumps, several products showed promising results. Further research with water solutions is suggested, since in some circumstances, the use of water solutions might greatly reduce the cost of killing undesirable red maple stump sprouts.

SUMMARY

Several herbicides were tested for preventing sprouting from recently-cut red maple stumps, and for killing established sprouts on older stumps.

The esters of 2,4,5-T, when used in oil solution at concentrations of 12 lbs. ahg. and 16 lbs. ahg., respectively, were completely effective when applied to both freshly-cut stumps, and old stumps with established sprouts.

The water solutions were not as effective as the oil solutions, but, on new stumps, products containing polychlorinated benzoic acid, triethylamine salt of 2,4,5-T and propylene glycol butyl ether ester of 2,4,5-T, gave promise of having considerable value. The triethylamine salt of 2,4,5-T showed the best results. Treatments of the older stumps showed similar results, except for some differences among the variably-sized sprouts on the older stumps.

THE EFFECT OF VARIOUS LIGHT INTENSITIES ON EGG PRODUCTION OF SINGLE COMB WHITE LEGHORN PULLETS[1]

By C. E. OSTRANDER[2], R. K. RINGER and H. C. ZINDEL

Department of Poultry Science, Michigan State University, East Lansing, Michigan

and

C. N. TURNER

Department of Agricultural Engineering, Cornell University, Ithaca, New York

Artificial lighting in commercial poultry houses has been receiving renewed attention in recent years. The use of artificial lights to increase egg production during the period of short light days has been known for many years (2, 5). Whetham (8) indicated that the amount of light per day was more important than intensity of light. Several workers including Dobie, Carver and Roberts (1) and Nicholas, Callenbach and Murphy (4) have reported on the use of various intensities of light and its effect on egg production. These latter workers reported that birds receiving high light intensities, in the range of 30 to 38 foot-candles, produced no more eggs than birds receiving low intensities (0.5 to 1.0 foot-candle). Dobie, Carver and Roberts (1) tested intensities from 1.0 foot-candle to 31.3 foot-candles at the feeders and found no increase in egg production from the use of intensities above 1.0 foot candle.

Platt (6) showed that pullets lighted by 10-watt red bulbs placed over the roosts yielded as many eggs as those pullets lighted by 60-watt incandescent bulbs which were located over the floor area.

During the past few years there has been considerable promotion in the field for the use of bright lights in laying pens. These lights give intensities ranging from 2 to 9 foot-candles at the feeder level.

[1]Taken from unpublished thesis. Research conducted at Cornell University and submitted as partial fulfillment of the M.S. degree while at Michigan State University.

[2]Graduate student-candidate for M.S. degree at Michigan State University. Present address: Department of Poultry Husbandry, Cornell University, Ithaca, New York.

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such intensities are produced by certain types of reflectorized, incandescent bulbs of 100- to 150-watts or through the use of fluorescent bulbs.

The objective of this investigation was to further evaluate the effect of specific intensities of light on egg production.

EXPERIMENTAL

On October 1, 1959, 1,040 Single Comb White Leghorn pullets (Cornell strain) were housed. One hundred thirty pullets per pen were placed into eight 20′ x 20′ pens. Natural light reached these shed-type pens through windows in the front (south side) and through two small windows under the dropping boards at the rear (north side). Replicate pens were lighted as follows:

II and IX two 60-watt incandescent bulbs

III and VIII two 40-watt fluorescent bulbs

I and X two 100-watt incandescent bulbs; and

V and VI four 15-watt incandescent red bulbs with the red bulbs placed 18 inches over the heads of the birds on the roosts (Figure 1).

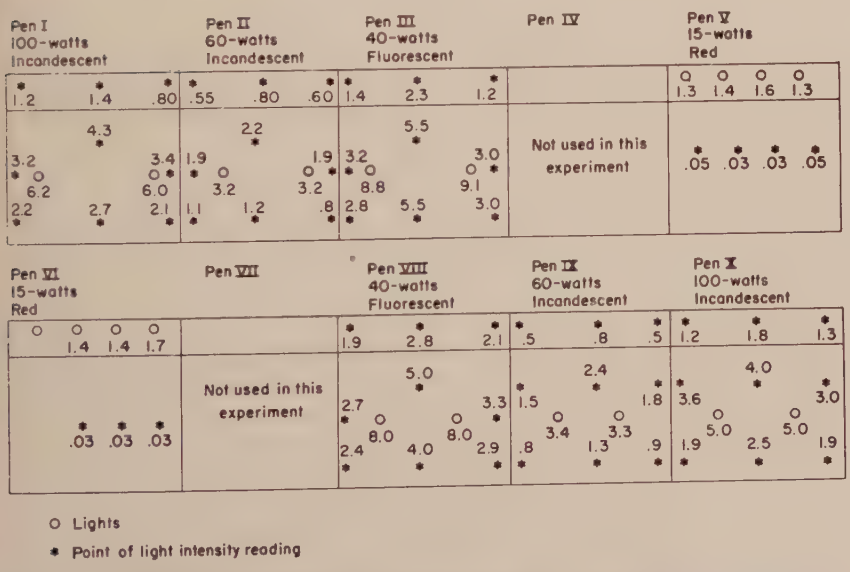

Fig. 1. Experimental design of pens showing light intensities in foot-candles at different locations.

No reflectors were used for any bulb. Light intensities were measured by using a General Electric PF 13 light meter of the type used to determine the intensities of city street lights.

All birds were provided with a 14-hour light period by mechanically turning the lights on at 5:00 a.m. and off at 8:00 a.m. and on at 4:00 p.m. and off at 7:00 p.m. This provided six hours of artificial light plus eight hours of daylight, for a total of 14 hours of light per day. Due to lack of time and space, it was decided not to compare a naturally lighted pen to 14 total hours of artificial and natural light. The literature is replete in showing the benefits from 14 hours of light. A 16 percent all-mash laying ration was fed *ad libitum* throughout the test. Water was available at all times.

RESULTS

Egg production per bird, by four-week periods, is shown in Table 1. It can be seen from Table 1 that no advantage in egg production was obtained by using intensities higher than those provided by 60-watt incandescent bulbs. The birds receiving light from 15-watt red bulbs, placed over the roosts, produced as well as those birds on any

TABLE 1—Light intensity and its effect on eggs produced per bird recorded in 4-week periods

Bulb	Total light (daylight+artificial light) equals 14 hours							
	15-watt Red		40-watt Fluorescent		60-watt Incandescent		100-watt Incandescent	
Pen number	V	VI	III	VIII	II	IX	I	X
Periods	No. eggs	No. eggs	No. eggs	No. eggs	No. eggs	No. eggs	No. eggs	No. eggs
0-4	18.5	17.9	16.6	17.4	18.7	22.1	19.1	20.5
4-8	17.4	19.5	15.7	17.1	18.7	19.4	18.2	18.5
8-12	16.4	17.1	14.2	16.4	16.9	17.3	16.2	16.5
12-16	16.2	16.2	14.0	16.4	16.1	16.5	14.5	14.8
16-20	14.9	16.2	13.0	15.5	15.4	17.2	14.5	14.9
21st week	3.4	4.0	2.9	3.9	3.6	4.2	3.5	3.5
Total	86.8	90.9	76.4	85.7	89.4	96.7	86.0	88.7
Average of replicates	88.8		81.0		93.0		87.3	
Percent mortality	2.65		3.05		8.05		2.25	

f the other treatments. The birds receiving light from 40-watt luorescent bulbs did not produce as well as those on other treatments, ut the difference was not statistically significant.

Feed efficiency, as measured by pounds of feed per dozen eggs roduced, was recorded. No treatment had an advantage over any ther treatment in pounds of feed required to produce a dozen eggs (Table 2).

ABLE 2—Light intensity and its effect on feed efficiency measured in pounds of feed per dozen eggs produced in 4-week periods

Bulb	Total light per day (daylight+artificial light) equals 14 hours							
	15-watt Red		40-watt Fluorescent		60-watt Incandescent		100-watt Incandescent	
n numbers	V	VI	III	VIII	II	IX	I	X
	Pounds of feed per dozen eggs							
eriods								
0-4	4.0	3.6	4.5	4.2	4.5	4.2	3.8	3.6
4-8	4.3	4.3	4.7	4.3	4.6	4.3	4.1	4.5
8-12	4.5	3.8	5.2	3.9	4.5	4.4	4.6	4.0
12-16	4.6	5.2	5.4	4.5	5.4	5.2	5.2	5.1
16-20	3.1	3.5	3.7	3.6	3.9	4.0	3.9	4.4
verage	4.1	4.1	4.7	4.1	4.6	4.5	4.3	4.3
verage of replicates	4.1		4.4		4.5		4.3	

DISCUSSION

The 100-watt incandescent or 40-watt fluorescent bulbs gave ntensities at the feeders as high as 8 to 9 foot-candles, which were nore than twice those produced by the 60-watt and several times those f the 15-watt incandescent bulbs. However, the pullets housed in pens ighted by 100-watt incandescent or 40-watt fluorescent bulbs did not roduce any more eggs than the birds in pens lighted by 60-watt or 15-watt incandescent bulbs.

Based on these data, it appears that no additional advantage can e obtained from the use of high intensities over that obtained from 0-watt bulbs without reflectors. These results further substantiate he work of Dobie, Carver and Roberts (1).

It has been reported that red and orange rays of the visible spec- rum stimulate the hypophysis (commonly known as the pituitary)

gland giving maximal egg production but yellows, greens and blues are relatively ineffective (7). Though the light intensity meters used were designed to measure wavelengths to which the human eye responds, these intensities are not necessarily indicative of the wavelengths that produce optimum stimulus for maximum egg production. However, this has been an accepted method of measuring effects of artificial illumination for laying birds, using lamps designed for human vision. The comparable production of eggs under 8.0 to 9.1 foot-candles when fluorescent lights were used with that at light intensities of 0.03 to 0.05 foot-candles at the feeder level and 1.3 foot-candles at roost level when 15-watt red lights were used tends to substantiate the previous statement and the findings of Platt (6).

The high initial cost of fluorescent light fixtures, the fact that they produced no more red rays than the incandescent bulbs, their low output in cold temperatures, coupled with no increase in egg production, makes the use of fluorescent lights for poultry houses less profitable than the use of incandescent bulbs. At an estimated electrical cost of two cents per kilowatt hour, using a 40-watt fluorescent versus 60-watt incandescent bulbs, it would take several years to save enough money to pay for the difference in the installation cost of fluorescent lamps in place of incandescent bulbs. The saving in electricity, for a lighting period of 250 days, amounts to $1.20 per year per fixture if a 60-watt bulb is used instead of a 100-watt bulb (250 days x 6 hrs/day x 40-watts saved x $.02 = $1.20 per year) and no added production is obtained as in the experiment reported. This saving could be considerable for a large commercial poultry operation.

SUMMARY

There was no statistically significant difference in egg production from Single Comb White Leghorn pullets housed in pens lighted by 100-watt incandescent, 40-watt fluorescent, 60-watt incandescent or 15-watt red bulbs when these red bulbs were placed 18 inches over the heads of the birds on the roosts.

The feed consumption per dozen eggs was comparable in all treatments.

Based on this test, it appears that there is no advantage from supplying high intensity light in pens containing laying birds.

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VIRGINIA CRAB APPLE STOCK SHOWS SOME RESISTANCE TO GIRDLING BY MEADOW MICE

By WALTER TOENJES

DEPARTMENT OF HORTICULTURE

TRUNK-GIRDLING of apple trees by the meadow mouse[1] may be an annual problem for many fruit growers. Practices generally employed to prevent tree damage by this rodent include placing wire guards around the tree trunk, clearing away sod growth and mounding soil against the trunk, spraying the ground area beneath the trees with rodenticides, and spreading poison baits in the orchard. Individually, each of these control measures is costly from the standpoint of labor and materials.

The use of understocks that indicate some mouse resistance may eventually add another control measure to those named. Observations at the Michigan State University Graham Experiment Station, Grand Rapids, over a period of years appear to indicate that the bark of some apple varieties is more palatable to the meadow mouse than that of other varieties. For example, in the Graham Experiment Station nursery, 17 one-year-old trees of an unnamed sweet apple were completely girdled, while adjacent trees of McIntosh and apple seedlings of the same age were not touched.

Similarly, of 137 three-year-old Hibernal trees in the nursery, approximately one-half were partially to totally girdled, while 147 Virginia Crab trees of the same age in an adjacent row showed no evidence of mouse injury. Further, unconfirmed reports from several fruit growers stated that mouse girdling was confined to the interstem piece used in the process of producing dwarf apple trees.

Procedure

To further explore the possible mouse resistance of Virginia Crab, studies were undertaken at the Graham Station during the winters of

[1] *Microtus pennsylvanicus pennsylvanicus.*

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953 - 1954, and 1956 - 1957. Four plots, mulched to a depth of 6 nches with wheat straw, were established in an apple orchard grow- ng in sod, Fig. 1, and three plots in a heavy grass sod area covered ith straw mulch adjacent to the orchard, Fig 3. The 1956 - 1957 plots ere confined to the mulched area adjacent to the orchard.

Fig. 1. This is the arrangement of straw mulch plot and branches under a apple tree growing in sod. See Fig. 2 for the extent of mouse chewing on hese branches.

To simulate trees, freshly cut branches were sharpened and driven hrough the mulch and into the soil to a depth of 7 inches. The ranches were about 3 feet long, from 2 to 3 inches in diameter, and onsisted of three-to five-year-old wood. Three branches each of the arieties McIntosh, Jonathan, Red Delicious, Northern Spy, and Vir- ginia Crab were arranged at random in each grass sod-mulch plot. In oth years the branches were placed in position in late December and valuated in late April for damage by the feeding of field mice.

Results

Figure 2 is a closeup view of the branches used in Fig. 1. The three Virginia Crab branches on the extreme left in Fig. 2, showed no evidence of mouse girdling. Seven of the remaining 12 branches were partially or completely girdled. Judging from the mouse runways in

evidence, only a moderate mouse population frequented this plot during the winter of 1953 - 1954.

Greater mouse activity and more severe girdling of the branches occurred in the plot shown in Fig. 3. A close view of the branches from this plot are shown in Fig. 4. All branches, with the exception of Virginia Crab on the extreme left, were completely girdled, and over an extended area. The scattered areas of chewed bark on the Virginia Crab branches are mostly superficial, showing only an occasional small area where the bark had been removed to expose the wood below. This type of injury would not have been considered harmful had it occurred on a tree growing in the orchard.

Fig. 2. Close view of branches in Fig. 1 Varieties from left to right are: uninjured Virginia Crab, Jonathan, Red Delicious, McIntosh, and Northern Spy.

Meadow mice failed to frequent, to any extent, the remaining three plots located in the orchard, and the two plots in the heavy grass sod area during the winter of 1953 - 1954. Only one to three branches in each of these plots showed even slight to moderate amount of chewing, and this was confined to the varieties other than Virginia Crab. Similar conditions of mouse activity prevailed in the 1956 - 1957 straw plots, which in turn provided no additional data of value on the degree of mouse resistance of the Virginia Crab.

Fig. 3. Straw mulch plot and branches located in a sod area having a heavy population of meadow mice. See Fig. 4 for the extent of mouse chewing on these branches.

Fig. 4. Close view of the branches in Fig. 3. The chewing damage on the four Virginia Crab branches on the left is mostly confined to the outer bark and would not be considered injurious to a tree. The remaining branches from left to right are: McIntosh, Jonathan, Red Delicious and Northern Spy. On these the bark was completely removed by the mice to the wood below and to a length of from 10 to 12 inches on the Red Delicious and Northern Spy varieties.

Discussion and Summary

The observations and limited data presented indicate some mouse resistance of the Virginia Crab bark.

The extent of girdling of the branches in the mulch plots appears closely associated with prevailing mouse populations. Where the population and activity was only moderate some girdling occurred on the branches of the four commercial apple varieties, but not on the Virginia Crab. Under more severe and intensive mouse activity the Virginia Crab bark still appeared to be unpalatable to the meadow mouse. This suggests that the use of Virginia Crab as an understock for other apple varieties, could materially reduce trunk girdling by this rodent in apple orchards.

FURTHER STUDIES OF THE RELATION OF SUGAR-ACID RATIOS TO THE RIPENING AND DETERIORATION OF JERSEY AND RUBEL BLUEBERRY FRUIT

By R. C. BOWERS[1] and D. H. DEWEY

DEPARTMENT OF HORTICULTURE

THE STUDIES BY WOODRUFF et al.[2] showed that excessive deterioration of highbush cultivated blueberries following harvest was associated with a high incidence of overripe fruit. The sugar and acid content of the berries was related to the degree of ripeness, and a ratio of these constituents was proposed as a basis for a harvest index chart for the Jersey variety[3].

Further study of the sugar-acid ratio changes with ripening of this variety, as well as for Rubel, another important Michigan variety, was desirable. The present studies furnish additional knowledge toward developing a practical means of objectively selecting the proper time of harvest for blueberries of optimum dessert quality and maximum market and storage life.

METHODS

The sugar and acid changes associated with ripening were ascertained with blueberries of known physiological age. About the time of first commercial harvest, when the berries were ripening in abundance, all of the berries that were blue in color were removed from 18 uniform Jersey and 18 uniform Rubel bushes. The next day, on July 21, 1960, all berries that had become red or blue in color were individually tagged.

Two pints of tagged fruit of each variety were picked at random

[1]Present address: Department of Horticulture, University of Arizona, Tucson, Arizona.

[2]Woodruff, R. E., D. H. Dewey and H. M. Sell (1960). Chemical changes of Jersey and Rubel blueberry fruit associated with ripening and deterioration. *Proc. Amer. Soc. Hort. Sci.* 75: 387-401.

[3]Woodruff, R. E. and D. H. Dewey (1959). A possible index for Jersey blueberries based on the sugar and acid contents of the fruit. Mich. Agr. Exp. Sta. Quart. Bul. 42(2): 340-349.

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from the 18 bushes on the day of tagging, and subsequently at 4-day intervals for a period of 20 days.

Soluble solids readings of the juice from three samples of 20 berries were taken in the field at the time of harvest with a Ziess-Opton hand refractometer. Harvested berries were selected at random and placed into a milk filter pad and mascerated by squeezing with the fingers. The juice for the reading was obtained by further squeezing the sample after several drops of juice had been discarded. The remaining berries were placed in plastic bags and packed in a cooler containing dry ice for transport to East Lansing where they were held at -10° F. for later chemical analysis.

Total acids were determined for the frozen sample by the standard A.O.A.C.[4] method. A 50 g. sample of frozen berries was blended with 150 ml. water and then filtered through a single thickness of cheese cloth. An initial pH reading was made on a 100 ml. aliquot before titrating to an end point of 8.1 with 0.1 N NaOH. Total acid was expressed as percent citric acid. Total sugar, expressed as percent dextrose, was determined by the Lane-Eynon[5] method using 50 g. of frozen berries. All samples were analyzed in duplicate.

Five plots of Rubel bushes at different locations were selected to study the relationship of initial harvest date upon the sugar-acid ratio. Each plot consisted of 20 full grown, vigorous bushes which had not been previously harvested during the current season.

Five pickings at 4-day intervals were made at each plot. Berries were harvested from a different set of four bushes at each of the harvest dates; thus, each harvest represented an initial picking. The harvest dates were initiated as soon as 11 pints could be obtained from the four bushes.

All of the blue-colored fruit were harvested from randomly selected clusters. Three samples of 20 fruit were taken for immediate determination of soluble solids. One pint of fruit was frozen in a plastic bag for later measurements of total sugar, total acid, and pH. Six pints were placed at 40° F. for 18 days and 4 pints at 75° F. for 6 days for evaluation of deterioration. Deterioration was classified into two types—stem scar decay and "runny soft", and was expressed as percent breakdown on a fresh weight basis.

Stem scar decay was characterized by slight indentation and

[4]Association of Official Agricultural Chemists (1955). *Official Methods of Analysis.* 8th Ed. George Banta Pub. Co., Menasha, Wisconsin. p. 354.

[5]Lane, J. H. and L. Eynon. Determination of reducing sugars by means of Fehling's solution with methylene blue as internal indicator. *Jour. Soc. Chem. Ind.* 42: 32-37, 1923.

browning of the skin and flesh at the area of stem attachment. The flesh of "runny soft" berries became completely disintegrated so that upon slight pressure from the fingers the berries fell apart. There was some mycelium associated with the stem scar decay, but generally there was no indication of secondary infection on "runny soft" berries.

RESULTS AND DISCUSSION

Marked changes in the sugar and acid content of Rubel and Jersey fruit occurred during the first 4 days following the appearance of red coloration in the skin (Table 1) and indicated that the ripening processes were rapid for this period. Full ripeness was probably attained when the maximum sugar and the minimum acid levels were reached at 8-12 days. Berries picked at 8 days were of acceptable market quality as determined by taste; whereas, those picked at 0 and 4 days were unsatisfactory because of excessive tartness.

The changes in sugars and acids followed patterns similar to those reported by Woodruff et al.[6] Jersey fruit had a lower sugar

[6]See footnote 2.

TABLE 1—Changes in pH, soluble solids, total sugar, titratable acid, and sugar-acid ratio during ripening of Rubel and Jersey blueberry fruit

Days after red coloration	Percent soluble solids	Percent total sugar	pH	Percent titratable acid	Sugar-acid ratio
			Jersey		
0	12.4	7.6	2.98	1.34	5.7
4	13.9	9.9	3.32	.67	14.8
8	13.6	10.9	3.73	.31	35.2
12	14.6	11.8	4.16	.25	47.2
16	14.3	11.9	4.29	.19	62.6
20	13.6	11.5	4.18	.20	57.5
			Rubel		
0	12.8	7.5	2.82	1.95	3.9
4	13.3	11.9	3.30	.77	15.5
8	14.1	11.7	3.59	.51	22.9
12	15.3	12.7	3.74	.44	28.9
16	14.5	11.6	3.85	.42	27.6
20	13.8	12.8	3.89	.36	35.6

and acid content and the change in these constituents during the harvest period was less in 1959 than in the previous year. The sugar-acid ratios (Fig. 1) were higher throughout the 1959 test period than in the previous year for the Jersey variety. The sugar-acid ratios for the Rubel variety (Fig. 1) were the same at 0 days, higher at 4 and 8 days, and lower at 12, 16 and 20 days after red coloration in 1959 than in 1958. Examination of weather records showed similar conditions of temperature and rainfall existed during the harvest periods in both years. Other factors such as number of hours of sunshine,

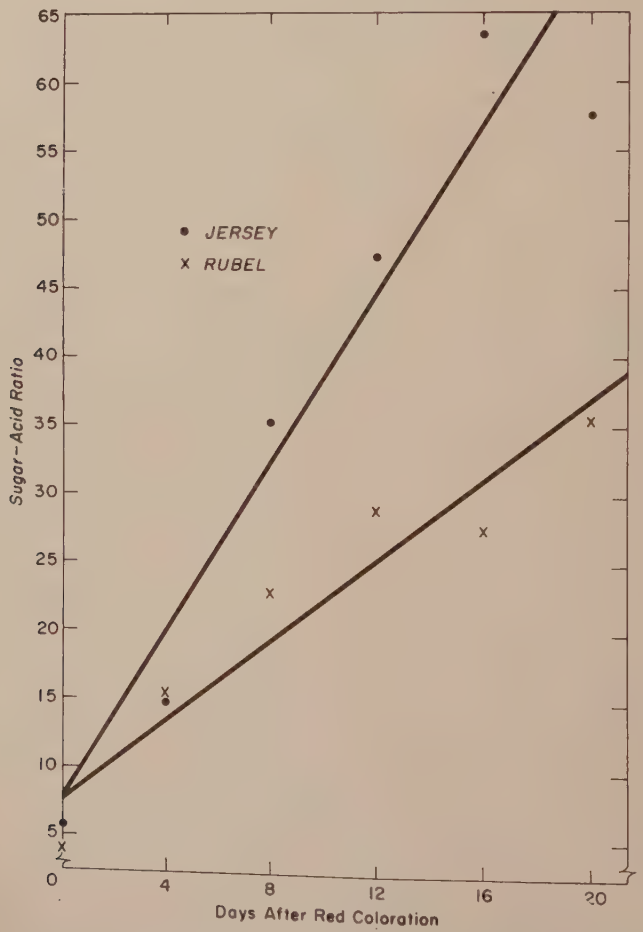

Fig. 1. The relationship of sugar-acid ratio changes to days after red coloration for Rubel and Jersey blueberry fruit.

berry size, yield, pruning practices, nutritional status, and irrigation may have affected the sugar and acid contents resulting in the observed difference.

The varietal differences in sugars and acids observed in 1958 (Woodruff, *et al.*[7]) were confirmed. In both years the Rubel fruit had a higher acid content and usually a slightly higher sugar content than Jersey. As shown in Fig. 1, the Rubel variety had lower sugar-acid ratios than Jersey.

[7]See footnote 3.

TABLE 2—The soluble solids, pH, sugar and acid contents, sugar-acid ratios, and breakdown of Rubel blueberries harvested periodically at five locations in western Michigan.

Plantation	Date of harvest	Percent soluble solids	Percent sugar	pH	Percent acid	Sugar: acid	Percent breakdown	
							6 days at 75° F.	18 days at 40° F.
Bangor	July 9	14.5	9.1	2.87	1.66	5.5	35.8	29.9
	13	14.4	9.9	3.00	1.30	7.6	33.2	13.2
	17	15.2	8.4	3.12	1.00	8.4	45.9	12.7
	21	15.0	12.0	3.43	.76	15.8	77.3	28.5
	25	14.8	9.5	3.52	.67	14.2	73.7	30.5
Allegan	July 13	15.6	10.5	3.25	0.98	10.7	54.0	39.1
	17	17.8	12.4	3.40	.89	13.9	61.6	36.7
	21	18.7	12.1	3.65	.60	20.2	56.0	31.1
	25	17.7	12.3	3.98	.44	28.0	77.1	41.6
	29	15.8	11.9	3.97	.42	28.3	82.4	54.7
Lacota	July 17	15.1	11.3	3.07	1.25	9.0	28.3	4.7
	21	15.6	10.7	3.17	1.00	10.7	67.9	21.2
	25	14.8	12.2	3.34	.69	17.7	61.7	17.7
	29	14.7	11.7	3.43	.65	18.0	54.3	36.5
	Aug. 2	15.2	11.5	3.51	.57	20.2	63.7	28.5
Douglas	July 25	14.2	9.8	3.13	0.93	10.5	47.8	14.4
	29	15.6	10.7	3.25	.84	12.7	35.5	6.7
	Aug. 2	14.7	11.3	3.39	.75	15.1	45.6	17.9
	6	15.1	10.0	3.50	.61	16.4	74.2	31.6
	10	14.8	11.0	3.60	.53	20.8	59.9	28.0
Holland	July 29	15.4	11.6	3.45	0.69	16.8	53.1	10.5
	Aug. 2	16.0	8.8	3.48	.65	13.5	63.6	35.6
	6	17.0	12.4	3.54	.64	19.4	55.2	13.8
	10	16.7	12.7	3.53	.59	21.5	53.5	13.6
	14	16.3	11.7	3.66	.46	25.4	64.2	34.4

The general agreement of the sugar-acid ratios obtained in these tests with those previously reported for fruit of known physiological age[8] is good evidence that the ratio is a valid measure of the degree of ripeness.

Delaying the date of initial harvest of Rubel resulted in an increased sugar-acid ratio and a greater amount of deterioration upon holding (Table 2). This was true for all five of the test plots. Although deterioration at both 40° and 75° F. was significantly correlated to sugar-acid ratio (Fig. 2), a higher correlation value existed

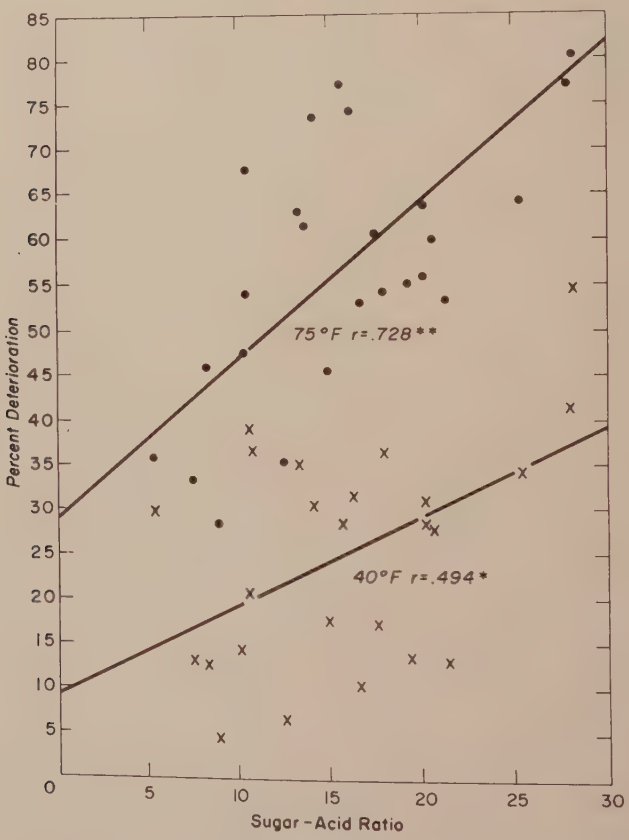

Fig. 2. The linear relationship of deterioration and the sugar-acid ratios of Rubel blueberry fruit. (D.F.=23; at 75° F., Y=29.32+1.73×; at 40° F., Y=9.15+1.01×).

[8]Ibid.

or the higher holding temperature. It was observed that the fruit held at 75° F. had a high incidence of "runny soft" breakdown, while much of the deterioration at 40° F. was stem scar decay.

The further evidence found here for a definite association of sugar-acid ratio and shelf life made it desirable to explore other methods of determining this ratio which would be simpler and possibly practical for field use. Woodruff and Dewey[9] found estimated sugar-estimated acid ratios and soluble solids-estimated acid ratios were directly correlated to percent breakdown of Jersey fruit. The same was found to be the case in the present study for Rubel. Highly significant correlations existed between these ratios and percent deterioration of fruit held 18 days at 40° F. ($r = 0.635$) and 6 days at 75° F. ($r = 0.636$) as shown in Table 3.

TABLE 3—The linear correlation coefficients of sugar and acid measurements to the breakdown of Rubel blueberry fruit held 18 days at 40° F. and 6 days at 75° F.

Index	Fruit deterioration			
	18 days at 40° F.		6 days at 75° F.	
	Correlation coefficient	S.E. of estimate	Correlation coefficient	S.E. of estimate
Percent sugar	0.109	.....	0.277	.....
Percent acid	−.389	.....	−.704**	10.51
Sugar: Acid	.494*	11.07	.728**	10.15
Soluble solids	.283	.....	.273	.....
Soluble solids: H-ion	.635**	9.83	.636**	11.43
Estimated sugar	.286	.....	.279	.....
Estimated acid	−.502*	11.01	−.754**	9.72
Estimated sugar: Estimated acid	.593**	10.25	.686**	10.76

*Significant at the 5 percent level.
**Significant at the 1 percent level.

Linear correlations (Figs. 3 and 4) showed that percent sugar can be estimated from soluble solids and percent acid from pH. There were highly significant relationships of the ratios of these estimated constituents to percent breakdown at 40° ($r = 0.593$) and 75° F. ($r = 0.686$).

Sugars alone, whether expressed as percent total sugar, soluble solids, or estimated percent sugar, were not related to percent breakdown (Table 3). However, percent of actual acid was highly related

[9]Ibid.

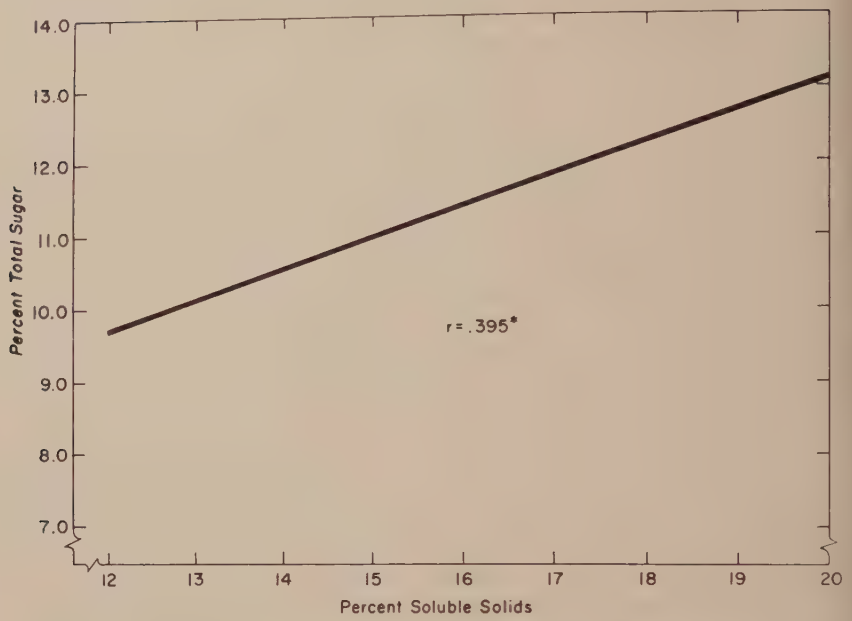

Fig. 3. The linear relationship of total sugar and soluble solids of Rubel blueberry fruit. (D.F. = 29, Y = 4.63 + .42×).

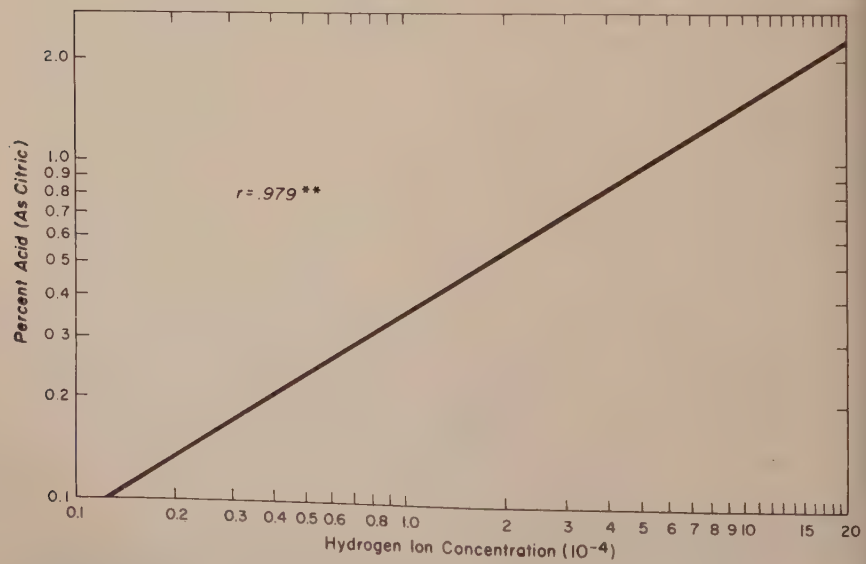

Fig. 4. The linear relationship of acid (expressed as citric) and hydrogen ion concentration of Rubel blueberry fruit. (D.F. = 29; Y = 0.25 + 0.11×).

) percent deterioration after 6 days at 75° F. Estimated acid (from H) was significantly associated with percent breakdown after 18 days t 40° F., and highly significantly associated with breakdown after 6 ays at 75° F. (Table 3).

The highest correlation coefficient (and the lowest standard error f estimate) occurred for estimated acid and deterioration at 75° F.; owever, the r value for estimated acid and deterioration at 40° F. as less significant. The ratios of sugars to acids, whether determined s soluble solids:H-ion, or as estimated sugar:estimated acid were ighly significant at both temperatures. The ratios therefore were of igher accuracy than single factors for estimating the degree of fruit ipeness.

SUMMARY

Jersey and Rubel blueberry fruit of known physiological age with espect to ripening were analyzed for sugar and acid contents. The atios of these constituents were related in a linear and positive anner for 20 days following the appearance of red coloration of the ruit. Rubel berries had higher total sugar and titratable acid con- ent than Jersey berries at comparable stages of ripeness.

Rubel fruit samples containing berries of variable degrees of ripe- ess were obtained from a sequence of initial harvests of bushes from ive commercial plantations in western Michigan. The fruit soluble olids determined at harvest, and total sugars, titratable acids, and H determined from berries frozen immediately after harvest, were elated to deterioration of the fruit held for 6 days at 75° and 18 days at 40° F. Fruit breakdown was significantly correlated in a linear and positive manner to the sugar to acid, soluble solids to H-ion con- centration, and estimated sugar to estimated acid ratios of the fruit.

SOME OBSERVATIONS ON THE USE OF FRUIT PRESSURE TESTERS

By R. C. NICHOLAS
FOOD SCIENCE DEPARTMENT

THE MAGNESS-TAYLOR[1] fruit pressure tester (4) and instruments of similar design are commonly used to measure the firmness of various fruits and vegetables (2). The place of these tools in research is well established and they have much to recommend them: low cost, simplicity of operation, and portability. However, these instruments are used by people on biological materials. Apropos variations (such as seasonal) in test results, Smock and Neubert (6) have remarked that ". . . . limitations of the test are so numerous that it raises the question of just what real value the test may have." Nevertheless, there remain convincing data exhibiting a relationship between pressure test measurements and, for example, maturity. Moreover, the use of any mechanical device implies some degree of objectivity, and no comparably simple test has been offered as a replacement for fruit pressure testers.

Studies of firmness of fresh cucumber pickles in this laboratory revealed significant differences in results between individuals making the test. As a result, a mechanical recording pressure tester (5) was designed and built to make firmness measurements free of personal idiosyncrasy. This paper reports comparison tests between individuals using the fruit pressure tester and the mechanical recording pressure tester and tests designed to reveal personal variations in the use of the fruit pressure tester.

EXPERIMENTS AND RESULTS

Pickle Tests

In a preliminary study of heat-softening of whole fresh cucumber pickles, jars of pickles were given various time-temperature treatments

[1]The tester used in this work is that modified and currently manufactured by D. Ballauf Manufacturing Co., Inc., Washington 1, D. C.

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a hot water bath (tests made in 1958). Table 1 gives the average orces obtained by two individuals[2] using the fruit pressure tester ith a 5/16-in. tip; each individual tested 10 pickles from each treatent, estimating each reading to the nearest 0.25 lb. Table 2 gives e analysis of variance of the data. The highly significant difference etween individuals is undesirable. This difference is further evident the treatment means, which were consistently higher as measured B.

ABLE 1—Average force, pound, to puncture whole fresh cucumber pickles

Indi-vidual	Treatments									Over-all mean
	Temperature, °F. 160			Temperature, °F. 180			Temperature, °F. 200			
	Heating time, min. 30	60	240	20	40	60	10	30	50	
A	12.5	13.4	12.4	13.8	10.8	10.8	13.1	10.1	7.4	11.59
B	14.4	14.8	14.0	14.6	13.0	12.4	13.3	12.4	7.9	12.98

After the mechanical recording pressure tester (MRPT) was built 1959), some comparisons were made between it and the Magness-aylor fruit pressure tester (FPT) on fresh cucumber pickles (3). In hese initial tests it was shown that the mean forces required to uncture the pickles were different as measured by the two machines.[3] owever, in this first comparison the machines were equipped with ips of different cross-sectional area. The ratio of MRPT force means

[2]Individuals, assigned letter designations in these tests, are identified by the same letter in all tests.
[3]The MRPT furnishes a force-vs.-displacement diagram, but, since the FPT gives only the maximum force within the first 5/16-in. of penetration, maximum forces given by the two machines are reported throughout this work.

TABLE 2—Analysis of variance of whole fresh cucumber pickle force data (see Table 1)

Source	Degrees of freedom	Mean square
Treatments	8	82.6**
Individuals	1	86.8**
Interaction	8	2.55
Error	162	3.46

**Significant, 1 percent level.

to FPT means for five groups of pickles (five different heat treatments) covering a force range of about 5-16 lb. was 1.3; if the force is assumed to be proportional to the plunger-tip area, the expected value of this ratio is 1.44. In subsequent studies the MRPT was fitted with an adaptor that accepts the same tips used with the FPT.

Following this preliminary comparison, a test between machines and individuals was made of salt-stock pickles as they came from the salting barrels; that is, before freshening. The barrels represent different pre-salting treatments. The 5/16-in. tip was used with both machines; the plunger velocity of the MRPT was 6.48 in./min. Each individual tested 50 pickles from each barrel with each machine; forces were estimated to the nearest 0.5 lb. The pickles were punched on one of the prominent lobes at a point half way between the ends. Since it was known that the pickles vary in firmness from stem end to flower end, the MRPT was run by both individuals in the hope of revealing any tendency of one individual to locate the plunger preferentially closer to one end.

Table 3 gives the mean forces (of 50 pickles) for each barrel as measured by each individual with each machine. An "F" test of the variance ratio (MRPT vs. FPT) showed the MRPT variance to be significantly larger. This difference in variance required breaking up the analysis into two parts (Table 4). The individual's variances were not significantly different. Note (Table 4) that the results with the MRPT reveal a significant difference among barrels (barrel 25 is different from barrel 26) even given the larger error mean square. The analysis reveals, as in the earlier test, a highly significant difference between individuals. There is good agreement between the variances of the fresh and salt-stock pickles as measured by individuals

TABLE 3—Average force, pound, to puncture salt-stock pickles

Machines	Individuals	Barrels			All-barrel means	
		25	26	27	Individual	Machine
MRPT	B	17.61	15.98	16.62	16.74	16.65
	C	16.83	16.20	16.67	16.57	
FPT	B	15.53	16.07	16.43	16.01	15.20
	C	14.34	14.57	14.28	14.40	

TABLE 4—Analysis of variance of salt-stock pickle force data (see Table 3)

Source	Degrees of freedom	Machine mean squares	
		MRPT	FPT
Individuals	1	2.17	195**
Barrels	2	31.9*	5.43
Interaction	2	7.16	6.00
Error	294	9.08	3.47

*Significant, 5 percent level.
**Significant, 1 percent level.

with the FPT (Tables 2 & 4). The difference in machine means (Table 3, barrels and individuals combined) is significant.

In another test individual C tested 150 salt-stock pickles from each of two barrels (FPT, 5/16-in. tip). The same number of pickles were tested by B with the MRPT (5/16-in. tip, plunger speed 6.48 in./min). These data are given in Table 5. Analyses of variance (not shown) of the data from the two barrels for each machine showed no significant difference between barrels, but a "t" test of the means of each machine (MRPT vs. FPT) showed significant differences between machines for both barrels. In this test individual C found means about 0.9 lb. lower than those found by the MRPT; in the previous test (Table 3) his barrel means were 1.5 to 2.9 lb. lower than those found by the MRPT on the same barrels. Table 6 shows the analyses of variance for each machine, all barrels combined. MRPT results by B and C were combined because the analysis showed no difference between individuals using the MRPT. The FPT data are by individual C. The MRPT variance is significantly larger than the FPT variance.

TABLE 5—Summary of salt-stock pickle force data

Statistic	Barrel 16		Barrel 21	
	Machine			
	MRPT	FPT[1]	MRPT	FPT[1]
Number	150	150	150	150
Mean, lb.	15.44	14.49	15.62	14.75
Variance	4.57	3.12	5.56	3.01
Range, lb.	10-22	11-20	9-22.5	10-22
Coefficient of variation, %	14	12	15	12

[1]Punched by C.

TABLE 6—Analyses of variance of salt-stock pickle data, all barrels combined (see Tables 3 and 5)

Source	Machines			
	MRPT		FPT	
	Degrees of freedom	Mean square	Degrees of freedom	Mean square
Among	4	63.9*	4	3.06
Within	595	7.05	445	3.11

*Significant, 5 percent level.

Implicit in these various analyses is the assumption of normality of the force distribution. Fig. 1 shows the cumulative force distribution on arithmetic probability paper for individual C using the FPT and for the MRPT (data from barrel 21). The data for C were grouped into 1-lb. intervals and tested by chi-square for normality; his distribution is not normal (5 percent risk).

Apple Tests

The apple was chosen to test the relationship between the two machines in the expectation that a single apple could be punched several times with no influence of one punch upon another. Thirty-five Jonathan apples were punched while still cold on the day they were removed from a controlled atmosphere storage (May 13, 1960). Each machine was fitted with a 7/16-in. tip; the MRPT was operated at 6.48 in./min. Each apple was punched eight times by B, four times with each machine—twice through the skin and twice with the skin removed. The apples were placed in a sand-filled Petri dish when punching with the MRPT to avoid damage to the side not being punched by reducing the pressure on that side; for hand punching with the FPT the apples were pressed firmly against a damp sponge.

The eight places punched, all located around the maximum circumference of the apple, were always punched in the same order, but the choice of method, which machine to use and whether to remove the skin, was decided by random numbers for each place. Imagine a coordinate system measured clockwise around the apple as seen facing the stem. The 0° point was chosen by B before the first random number was given. The order of punches, including a ran-

omly chosen method, was 0°—MRPT, without skin; 180°—MRPT, ith skin; 270°—MRPT, without skin; 90°—FPT, with skin; 45°—PT, without skin; 315°—FPT, without skin; 225°—MRPT, with kin; 135°—FPT, with skin.

Readings with the MRPT through the skin are not difficult to ake because the force-displacement curve reaches a sharp maximum efore the plunger tip has penetrated the recommended 5/16 in., but e readings without the skin are subject to bias because the force-isplacement curve (5) does not always reach a sharply defined aximum within the first 5/16-in. of penetration, but, instead, rises ery sharply in about 0.1 in., remains essentially constant for perhaps e next 0.2 to 0.4 in., and then begins to rise again. The measurement force required by the MRPT to penetrate the flesh only was there-

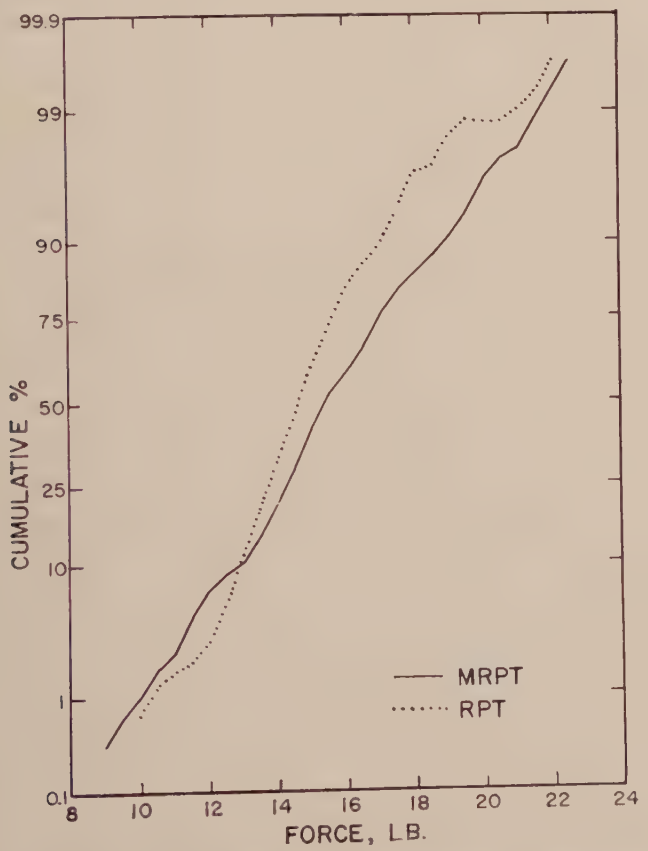

Fig. 1. Cumulative force distribution of salt-stock pickles.

fore taken as an estimate of the more-or-less constant force observed after the first rise. All measurements made with both machines were estimated to the nearest 0.2 lb. Measurements with and without skin were treated separately; the analyses of variance are given in Table 7. In this analysis the two like punches on each apple were regarded as the measure of error.

TABLE 7—Analyses of variance of apple force data

Source	Degrees of freedom	Mean square for methods	
		With skin	Without skin
Apples	34	1.05	0.823**
Machines	1	65.8**	18.2**
Interaction	34	1.33	0.253
Error	70	1.19	0.272

**Significant, 1 percent level.

Apples from the same lot were punched again after they had been in a conventional storage at 40°F for 4 days. Individual B punched 30 apples, first on the blush side, then 180° from the blush side (generally the green side), both punches without skin, and finally a point 90° from the blush side through the skin. All punches were made with the FPT fitted with a 7/16-in. tip.

The results of these two apple tests are given in Table 8. The given variances for the 5/13/60 punching are the combined variance of lot and apple. The blush and green side means are significantly different from the respective means obtained on the 13th with the

TABLE 8—Apple force data (7/16-in. tip)

Statistic	5/13/60				5/17/60		
	MRPT		FPT		FPT		
	With skin	Without skin	With skin	Without skin	Without skin		With skin, 90° from blush
					Blush	Green	
Mean, lb	12.01	8.79	13.02	9.51	10.98	10.63	13.73
Variance	1.25	0.354	1.56	0.453	0.853	1.14	0.898
Coefficient of variation, %	9.3	6.8	9.6	7.1	8.4	10	6.9

FPT. The difference between days for with skin means is significant.[4] The machine means, Table 7, both with and without skin, are again shown to be significantly different; however, the variances in this case are not significantly different. Individual B using the FPT got higher readings on apples (Table 8) than the MRPT, but lower readings on pickles (Table 3). More important is the result that both machines will distinguish among apples when punched without the skin; whereas, for the same apples punched with the skin, the data show that the variation on a single apple is just as large as the variation in the lot, a curious result in view of the fact that the skin is supported by the flesh.

Polyurethane Tests

A test was designed to examine the variation among individuals and the variation for one individual from day to day in the use of the FPT. For this purpose a material assumed to be free of daily change was selected, expanded polyurethane. This material shows a force-displacement curve surprisingly like apples punched without skin. Five individuals punched each of six 12″ x 17″ x 2″ polyurethane sheets at three places on each of six days (FPT, 7/16-in. tip). The six days were selected at random from the last 10 working days of the school year. Each individual kept his own daily record on a card, made up for each day, giving a randomized order of punching the sheets. The individuals were instructed not to consult other punchers and not to consult their own past records. The time of day to punch was chosen by the individual and was not necessarily the same time each day.

Tables 9a and 9b give a summary of the results; each item in the tables is the average of 18 readings. The force distributions for each individual were examined and none showed marked deviation from normality; individual ranges were within 0.4 lb. of each other (over-all range was 2.6 lb.), and individual standard deviations appeared to be similar. A plot of all the data on arithmetic probability paper showed no marked deviation from normality. Individual means, averaged over all sheets and all dates, fall into two groups as determined by Duncan's multiple range test (1): B,A,D,F; and D,F,E (in order of increasing mean force).

[4]These analyses are not shown. Only one of the appropriate readings from each apple punched on the 13th was used to make this and the previous comparisons (13th vs. 17th). In these cases the lot variation was treated as the measure of error.

TABLE 9a—Average force, pound, (all sheets combined) to puncture polyurethane sheets

Dates	Individuals					Date over-all means
	A	B	D	E	F	
5/23	10.61	10.42	10.30	10.70	10.47	10.500
5/25	10.53	10.47	10.43	10.51	10.18	10.424
5/27	10.53	10.39	10.59	10.73	10.77	10.602
5/31	10.37	10.46	10.66	10.57	10.46	10.500
6/1	10.09	10.19	10.42	10.58	10.57	10.369
6/3	10.19	10.31	10.27	10.52	10.30	10.318

The difference among sheets was not anticipated. The result was verified by tests with the MRPT (data not given). The six sheets used in this test were cut from a single large sheet which, according to both FPT and MRPT results, has firm regions around its edges. The individuals' variance (error mean square in Table 10) was significantly larger than the error variance found with the MRPT. Over-all force determined by the MRPT was 10.975 lb. Days were significantly different and divided themselves into four groups. The two Fridays are significantly different.

This experiment was repeated with some modifications on a larger group of people. Each of six sheets of polyurethane was divided into 100 squares 1 in. on a side by means of a removable frame to which a 10 x 10 reference grid was fixed (see Fig. 2). The order of punching the sheets was randomized for each individual and the order of the

TABLE 9b—Average force, pound, (all dates combined) to puncture polyurethane sheets

Sheets	Individuals					Sheet over-all means
	A	B	D	E	F	
1	10.47	10.41	10.67	10.63	10.51	10.538
2	10.56	10.72	10.61	10.63	10.64	10.633
3	10.32	10.07	10.32	10.48	10.12	10.262
4	10.41	10.32	10.26	10.70	10.68	10.473
5	10.40	10.54	10.52	10.60	10.34	10.482
6	10.17	10.17	10.29	10.57	10.43	10.324
Individual over-all means	10.387	10.372	10.444	10.602	10.456	10.452

TABLE 10—Analysis of variance of polyurethane force data (Tables 9a and 9b)

Source	Degrees of freedom	Mean square
Individuals	4	0.895*
Dates	5	0.952*
Sheets	5	1.69**
Interactions		
IxD[1]	20	0.347**
IxS[1]	20	0.278
DxS	25	0.180
IxDxS	100	0.182
Error	360	0.172

[1]Interactions combined to test main effects.
*Significant, 5 percent level.
**Significant 1 percent level.

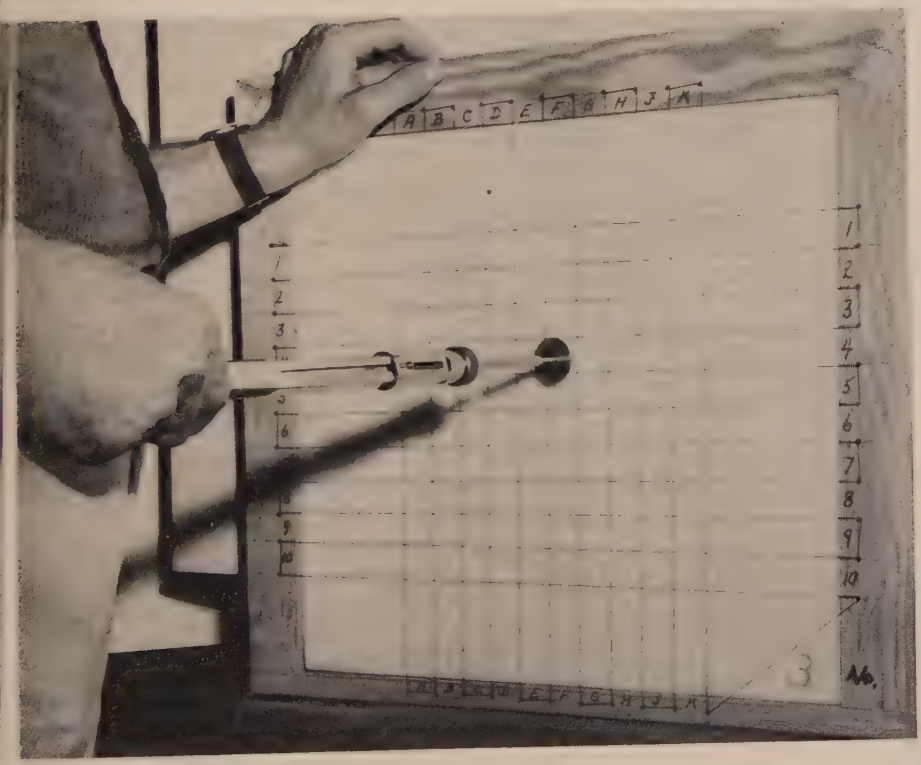

Fig. 2. Polyurethane sheet fitted in the reference-grid frame.

10 individuals was randomized for each of the five punching times. Each individual punched each sheet twice each time. The points to be punched on each sheet were randomly assigned to each individual. A recorder, who did not participate in the punching, read the FPT, which was held by the punchers so they could not see the force scale, and made all the records. No individual was informed of his results until the end of the test.

Individual means (all sheets combined) are shown for each time in Table 11; each item is the average of 12 punches. The analysis of variance of the data is given in Table 12. One individual's results were discarded from the analysis on the basis of a significantly large standard deviation. This individual had the highest mean force. The Individual-times-Time interaction is significant and somewhat larger than the corresponding interaction in the first polyurethane experiment. Sheets were significantly different, and firmer than the sheets in the previous test. Individuals were found to be significantly different; in order of increasing over-all mean force the three like groups (1) are M,H,F,J,L,P; H,F,J,L,P,D,G; and F,J,L,P,D,G,K. Note that D and F, who also participated in the previous test, are not now always found in the same group.

TABLE 11—Average force, pound, (all sheets combined) to puncture polyurethane sheets

Times	Individuals									Time over-all means
	D	F	G	H	J	K	L	M	P	
6/14 PM.....	11.18	10.88	11.25	10.93	11.15	11.08	11.18	10.90	11.27	11.093
6/15 AM.....	11.42	11.13	11.38	10.73	11.05	11.23	11.03	11.12	11.18	11.143
6/15 PM.....	11.12	11.15	11.07	10.68	11.10	11.82	11.28	10.98	11.18	11.154
6/16 AM.....	11.65	10.93	11.43	11.15	11.28	11.28	11.45	10.73	10.97	11.209
6/16 PM.....	10.95	11.33	11.27	11.37	11.00	11.55	11.05	10.88	11.48	11.209
Individual over-all means.....	11.264	11.087	11.280	10.974	11.117	11.394	11.200	10.924	11.217	11.161

DISCUSSION

These experiments have shown that when an individual uses a fruit pressure tester he exerts a measurable influence on the results of his tests. Measurements of the firmness of several materials are shown to be different depending on the individual making the measurement. Individuals have been shown to vary from time to time in their measurement of firmness of a single product. Comparisons of

TABLE 12—Analysis of variance of polyurethane force data (Table 11)

Source	Degrees of freedom	Mean square
Individuals	8	1.37*
Times	4	0.262
Sheets	5	2.67**
Interactions		
IxT	32	0.553**
IxS	40	0.260
TxS	20	0.454
IxTxS	160	0.310
Error	270	0.309

*Significant, 5 percent level.
**Significant, 1 percent level.

the variance of the force readings obtained by individuals using the fruit pressure tester with the variance obtained by a mechanical recording pressure tester show discrepancies depending on the product tested.

Individual differences in mean value are demonstrated in Tables 2, 4, 10, and 12. The natural course of action to avoid a discrepancy due to individuals is to have a single individual do all the punching required in any given experiment. But in special cases this practice may not be feasible; moreover, if there are differences among individuals, which one, if any, is measuring the true firmness, and does he always measure in the same way?

Significant variation among individuals from time to time is shown by the results given in Tables 10 and 12. Variation in time by a single individual is suggested by the differences found by B between 5/13/60 and 5/17/60 in both the with-skin and without-skin means in the same lot of apples (Table 8). The significant increase in firmness could be attributed to partial dehydration, but it could also be attribued to B. More important are the results shown in Table 6: here C is unable to distinguish among barrels which are different according to the MRPT results. The difference in this instance is small, but it is on the borderline of being worth further research. An important treatment effect might have been missed. If the MRPT is measuring the true firmness, it is possible to assign C's failure to distinguish the barrels by a chance (or psychological) variation between testing days. Conversely, it could happen that an individual reveals a significant dif-

ference where none exists. In all the tests presented in this paper the means determined by individuals were significantly different from those determined by the MRPT.

These differences among individuals from time to time are small but measurable. This variation as determined from the two polyurethane tests (Tables 10 & 12)—Individual-times-Days and Individual-times-Times interactions, respectively) amounts to 0.6-0.7 lb. In the case of pickles, the difference between individuals at a single testing time amounted to 12%. These variations, rather than the smaller error mean squares, provide the lower limits of precision to the experiments. If no greater precision is required, then, certainly, the use of the FPT is indicated. In the heat-softening experiment the precision required to determine adequately the heat-softening function was thought to be 0.5-1.0 lb., a confidence interval obtainable by increasing the number of pickles tested but, unfortunately, smaller than the difference between individuals and about as large as the day-to-day variation. Given this individual daily variation, how much unreliability that has been attributed to fruit pressure testers is, in fact, an unreliability in individuals?

The implications of the discrepancies in standard deviation are more subtle, but no less important. In all but one test, individuals working on the same material showed the same (statistically) standard deviation. The exception was a single individual punching polyurethane; however, his technique would be called into question by anyone familiar with the use of fruit pressure testers. The author believes that this individual is susceptible to training which would correct the unusual behavior.

In the pickle tests (Tables 4, 5, and 6) individuals using the FPT revealed a smaller lot variation in the product than did the MRPT. In the apple tests (Table 8) the individual's variance is not significantly different from that shown by the MRPT. In the first polyurethane test the individuals' variance was significantly larger than that shown by the MRPT (no MRPT test was made of the second polyurethane test sheets). The question is, which machine is measuring the true product variation? No efficient statistical design can be made without a knowledge of the product variation; moreover, in many instances product variation is itself an important consideration. The MRPT as a machine lends some *a priori* confidence in measurements made with it. It is not surprising that the MRPT shows polyurethane sheets to be more uniform than do individuals; the superiority of the machine is

accepted. But the significantly larger lot variance in pickles shown by the MRPT is disconcerting. If the individuals are telling the truth about pickles, the appropriate conclusion is that the MRPT is a less precise instrument, but if the MRPT is telling the truth, then one may conclude that individuals can and do measurably affect results.

The tests on apples are of some interest in that both FPT and MRPT showed a significant difference in the variance of a single lot of apples depending on whether the skin was removed. The smaller variance of the flesh (Tables 7 & 8) may have encouraged the recommendation that apples be tested with the skin removed because the results are said to be more consistent. The author opines that this reason is not a sufficient one for making measurements of the flesh only.

The two tests with polyurethane present a problem for further study. The error mean square in the second test (Table 12) is larger than that from the first test (Table 10) in which the individuals were permitted to make their own readings. The group is different, and the difference in variance may not be real, but the question as to how much a knowledge of previous results may affect future results is worth study.

SUMMARY

Measurable influence by individuals on the results of firmness tests made with a fruit pressure tester are demonstrated and discussed. Firmness measurements of several materials are shown to be different depending on the individual making the measurement. Individuals are shown to vary from time to time in their measurement of firmness of a single product. Comparisons of the variance of the force readings obtained by individuals using a fruit pressure tester with the variance obtained by a mechanical recording pressure tester show discrepancies depending on the product tested.

ACKNOWLEDGMENTS

The author wishes to thank the punching panel for its wholehearted cooperation and, in particular, Dr. J. A. Cook for his special contributions. The invaluable assistance of Dr. W. D. Baten, Experiment Station Statistician, is gratefully acknowledged.

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LETHAL EFFECT OF SMOKE ON SURFACE MICROORGANISMS OF CHEDDAR CHEESE

By T. I. HEDRICK, L. J. BRATZLER and G. M. TROUT

DEPARTMENT OF FOOD SCIENCE

MOLD ON THE SURFACE of Cheddar cheese is very undesirable. Such mold is unsightly, lowers the flavor quality of the cheese, and thus become an economic burden to the cheese industry. Mold growth, especially in packaged cheese stored for moderate periods of time in the home refrigerator, is also a problem.

The purpose of this investigation was to ascertain the lethal effect of smoking on surface microorganisms of Cheddar cheese. In a previous study[1] the beneficial effect of smoke on surface mold growth was observed.

Contradictory reports are to be found in the literature regarding the bactericidal effects of smoke on various kinds of meat or poultry. Gibbons[2] stated that dense smoke and high temperatures were more destructive to bacteria than lower temperatures. Light smoke was almost as effective as dense smoke. White[3] found that smoking reduced the number of bacteria 10-4 times its original number. Surface growth during storage was retarded by the smoke treatment. Malcom and Woodroof[4] reported the bacterial counts were not changed by smoking dressed turkeys.

EXPERIMENTAL

Cheddar cheese was cut into bars roughly 2 x 2 x 10 inches, weighing approximately 2 pounds each. The freshly cut bars of cheese, spaced on a one-half inch mesh wire screen to permit free

[1]Hedrick, T. I., L. J. Bratzler and G. M. Trout (1960). Smoke-flavored Cheddar cheese. Mich. Agr. Expt. Sta., Quart. Bul. 42: 714-721.

[2]Gibbons, N. E. (1954). Bactericidal and drying effects of smoking on bacon. Food Tech. 8:155-157.

[3]White, W. H. (1942). Smoked meats, bacteriological, chemical and physical measurements on smoked and unsmoked bacon. Canad. Jour. Res. 20(D): 263-275.

[4]Malcolm, H. R. and J. H. Woodroof (1957). Improved quality turkeys. Food Engr. 29: 121-123.

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smoke circulation on all sides, were transferred to a regular meat smokehouse where smoking was accomplished by conventional meat-smoking equipment, using hardwood sawdust.

Except for the hourly trials, the cheese was smoked from 5 to 6 hours. Temperature of the smokehouse during smoking varied with the trials. The temperature was controlled within a range of 4° to 10° F. by directing the smoke from the generator through water-cooled coils before flowing into the smokehouse. The cheese was smoked at low temperatures, 62° to 66° F., and at high temperatures, 90° to 94° F. During the smoking period, at half time, the cheese was turned once to expose the area in contact with the screen. After smoking the cheese was transferred to a 40° F. cooler and held overnight with care to prevent surface contamination.

The bacteria counts and the yeast and mold counts were determined by the swab technique described in the ninth edition of *Standard Methods for the Examination of Dairy Products*. Sufficient samples for adequate swabs were prepared and smoked as indicated above.

RESULTS AND DISCUSSION

The lethal effect of smoking Cheddar cheese is shown by data presented in Table 1. The bacteria count on the cheese surface just prior to smoking ranged from 1,800 to 28,000 per square inch with an arithmetic average of 15,100 for medium-cured Cheddar cheese. The surface count on aged cheese averaged 116,700 with a low of 7,200 and a high of 330,000 per square inch.

After one hour of smoking, the medium-cured samples averaged 410 within the extremes of 10 to 1,200 per square inch. The aged cheese varied from 5 to 13,000 with an average of 1,950 per square inch. Samples of medium-cured and aged cheese, with two hours of smoke exposure, had an average of 140 (<1 to 1,000 range) and 990 (<1 to 8,200 range) per square inch respectively. At three hours exposure, a further decrease in bacteria was observed. The average was 10 (medium cured) and 48 (aged) bacterial organisms per square inch.

Thereafter, a decrease in bacteria count occurred more slowly with some inconsistencies. These were attributed to the inherent variations incident to the swab test and variations in the original number of surface organisms among different samples. A different sample had to be used for each period of smoke-exposure time. The

higher average count for 8 hours of smoke exposure for both medium and aged cheese was due to results of one sample in both cases.

Bacteria counts were made on the smooth sides (no screen contact during smoking) and on the sides in contact with the wire shelving of the cheese surfaces. Slightly higher average counts were noted on the wire contact surface. Apparently the bacterial organisms on the surface in contact with the wire were partially protected until the samples were inverted mid-point in the smoking period.

The yeast and mold counts on the surface of the freshly cut medium-cured cheese before smoking ranged from <1 to 2,500 per square inch and <1 to 4,600 per square inch on the aged cheese (Table 1). The average of four trials on medium-cured cheese was

TABLE 1—The influence of smoke-exposure time on the numbers of microorganisms on the surface of Cheddar cheese

Smoke exposure (hours)	Bacteria (per sq. in.)			Yeast and mold (per sq. in.)		
	Medium cured (4 trials)					
	Average	Low	High	Average	Low	High
0	15,100	1,800	28,000	642	<1	2,500
1	410	10	1,200	<1	<1	2
2	140	<1	1,000	<1	<1	<1
3	10	<1	29	<1	<1	<1
4	3	<1	10	<1	<1	<1
5	2	<1	7	<1	<1	<1
6	2	<1	10	<1	<1	<1
7	1	<1	2	<1	<1	<1
8	*30	<1	242	<1	<1	<1
	Aged (9 trials)					
0	116,700	7,200	330,000	570	<1	4,600
1	1,950	5	13,000	1	<1	10
2	990	<1	8,200	<1	<1	1
3	48	<1	320	<1	<1	<1
4	*225	<1	3,200	<1	<1	<1
5	10	<1	58	<1	<1	<1
6	**96	<1	1,500	<1	<1	2
7	4	<1	26	<1	<1	<1
8	*57	<1	650	<1	<1	<1

*One sample had a high count.
**Two samples had a high count.

642 and on nine trials of aged cheese was 570. A drastic decrease in yeast and mold counts was evident after the first hour of smoke exposure. Most of the samples had <1 count and the others were low (10, 6, 2 and 2 per sq. in.). At the hourly tests between two and eight hours, the yeast and mold counts were virtually none.

Practically all of the organisms on the yeast and mold plates of swabs from the unsmoked cheese surface were molds. Only a few of the colonies were yeasts. The lethal effect of smoke was much more destructive to the surface molds than the bacteria during the first few hours.

The residual effect of five- or six-hour smoking seemed to continue for a few weeks after the smoking period. Cheese surface impregnation of the lethal smoke constituents is an explanation. Figure 1 illustrates the inhibiting effect of smoke on mold growth when samples were held several weeks. When smoked cheese was held at 54° to 56° F., surface mold growth did not become visible until approximately four to eight weeks. In the 40° to 42° F. storage, mold first appeared at approximately eight weeks on a few samples but more often at 10 weeks, and some samples did not show mold spots until 12 weeks.

Fig. 1. Freedom of surface mold growth (left) on Cheddar cheese as a result of smoke treatment.

Trials whereby the cheese surfaces were heavily seeded with molds also confirmed the lethal effectiveness of the hardwood sawdust smoke. However, a part of the delay in visible mold growth may have been due to dry crust on the surface of the smoked cheese samples.

SUMMARY AND CONCLUSION

Hardwood sawdust smoke was bactericidal against the surface bacteria of freshly cut Cheddar cheese. Initial counts of 1,800 to 330,000 per square inch of surface in 13 trials decreased to a range of 5 to 13,000 per square inch with one hour of smoking. Further decreases were noted at two and three hours of exposure. Thereafter, up to eight hours, the rate of bacteria destruction was minor.

Smoke at one hour exposure was highly effective in the destruction of viable yeast and mold on the cheese surfaces.

The smoke impregnated surface of the wrapped cheese resisted visible mold growth during storage at 40° to 42° F. for 8 to 12 weeks and for 4 to 8 weeks at 54° to 56° F.

THE INFLUENCE OF FLOOR SPACE ON EGG PRODUCTION AND FERTILITY OF BELTSVILLE SMALL WHITE AND BROAD BREASTED BRONZE TURKEY BREEDER HENS

By J. H. WOLFORD and T. H. COLEMAN

Department of Poultry Science

THIS EXPERIMENT WAS DESIGNED to determine the influence of the amount of floor space per turkey breeder hen on egg production, fertility and livability in both Beltsville Small White and Broad Breasted Bronze turkeys.

Recommendations concerning the amount of floor space per turkey breeder hen are based on opinion or "trial and error" rather than on experimentation. Marsden and Martin[1] recommend 12 square feet of floor space per hen for the large type turkey with 30 to 50 percent of the area on a sun porch. A commercial feed company publication[2] recommends housing large-type turkey breeder hens at the rate of 8 square feet of floor space per bird and small-type turkey breeder hens at the rate of 6 square feet of floor space per bird. According to Winter and Funk,[3] 8 to 10 square feet of floor space should be allowed per breeder hen. Recommendations similar to those stated above are found in a number of other commercial publications, magazines, and textbooks. In no case is scientific datum quoted as a basis for floor space recommendations.

PROCEDURE

Beltsville Small White turkey breeder hens were selected at random and divided into four unequal groups containing 30, 25, 20,

[1]Marsden, S. J., and J. H. Martin, 1949. *Turkey Management,* 5th Ed., p. 208. The Interstate Printers and Publishers Inc., Danville, Ill.

[2]Commercial Publication, 1954. *Turkey Management and Marketing, Wirthmore Feeds,* 4th Ed., p. 74.

[3]Winter, A. R., and E. M. Funk, 1956. *Poultry Science and Practice,* 4th Ed., pp. 520-521. J. B. Lippincott Co., New York.

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and 15 birds. Fifty-three Broad Breasted Bronze turkey breeder hens were selected at random and divided into four groups containing 9, 9, 15, and 20 birds. Each group within a variety was randomly assigned to a breeding pen. All pens used for the Beltsville Small Whites were approximately the same shape and size. Likewise, all pens utilized for the Broad Breasted Bronze breeders were approximately the same shape and size.

Each pen had the same amount of feeding and watering space regardless of the number of birds in the pen. Arrangement of equipment within pens was as nearly consistent as possible. Electric heating units were placed in the water pans to prevent ice formation and to provide warm water. All birds received the same turkey breeder ration throughout the experimental period.

Beginning January 2, 1959, the toms used in this study were subjected to a 14-hour light day. At the time toms were placed in the breeding pens with hens, January 26, 1959, lights were turned on in these pens. A 14-hour light day was maintained throughout the experimental period by using one 50-watt bulb located approximately 6 feet from the floor in each pen.

Eggs were saved for hatching from February 16, 1959, through June 7, 1959. Trapnests were used in all pens and the eggs were gathered five to six times daily. Settings were made at two-week intervals. At the end of 24 days of incubation all eggs were candled to determine fertility.

A summary of the number of birds per pen (male and female), number of square feet of floor space per pen and per bird, and the amount of feeding and watering space per bird is presented in Table 1.

RESULTS AND DISCUSSION

Eggs Produced and Set

In the case of both the Beltsville Small White and Broad Breasted Bronze turkey breeder hens, number of eggs produced per square foot of floor space increased as floor space per bird decreased. The number of eggs laid per hen tended to decrease in both varieties as floor space per bird decreased; however, the differences were not statistically significant (Table 2).

Factors other than floor space may have influenced egg production in this study. Since feeding and watering space was held constant

TABLE 1—Number of birds per pen, square feet of floor space per pen and per bird, and amount of feeding and watering space per bird

Pen	Variety(*a*)	Housed(*b*)	Floor space per pen (sq. ft.)	Floor space per bird (sq. ft.)	Feeding space per bird (inches)	Watering space per bird (inches)
2	BSW	30/2	75.4	2.36	1.5	.70
3	BSW	25/2	72.2	2.67	1.8	.85
4	BSW	20/2	67.6	3.07	2.2	1.05
5	BSW	15/2	74.1	4.36	2.8	1.35
12	BBB	20/2	49.9	2.27	2.2	1.05
11	BBB	15/2	48.9	2.88	2.8	1.35
18	BBB	9/1	58.0	5.80	4.8	2.30
9	BBB	9/1	65.9	6.59	4.8	2.30

(*a*) BSW—Beltsville Small White.
BBB—Broad Breasted Bronze.
(*b*) Hens/Toms.

TABLE 2—Influence of floor space per bird on production and mortality in Beltsville Small White and Broad Breasted Bronze turkey breeder hens

Pen	Hens/toms housed	Square feet per bird	Eggs set			Percent production(*a*)	Percent mortality(*c*)
			Total	Per hen(*a*)	Per sq. ft.		
A. Beltsville Small White							
2	30/2	2.36	1,436	47.9(*b*)	19.0	42.7	6.7
3	25/2	2.67	1,161	46.4	16.1	41.5	8.0
4	20/2	3.07	1,013	50.7	15.0	45.2	10.0
5	15/2	4.36	853	56.9	11.5	50.8	6.7
B. Broad Breasted Bonze							
12	20/2	2.27	999	50.0	20.0	44.6	0
11	15/2	2.88	734	48.9	15.0	43.7	0
18	9/1	5.80	404	44.9	7.0	40.1	0
9	9/1	6.59	509	56.6	8.6	50.5	0

(*a*) Based on number of hens housed.
(*b*) No significant differences were obtained between pens.
(*c*) Two birds from pen 2 (6.7%), one bird from pen 3 (3.7%) and one bird from pen 5 (6.7%) were removed because of positive reaction to the Salmonella Pullorum Tube Test 10 days after the experiment began. Later laboratory tests proved this reaction to be false.

per pen rather than per bird, insufficient feeding and watering space might have been partially responsible for the lowered egg production experienced in pens where less floor space was allowed per bird.

Fertility

Fertility in both varieties of turkey breeder hens tended to increase as floor space per breeder hen increased (Table 3). In addition to the possible influence of floor space, factors such as virility of males, number of females per male, and interference by other males and females during mating may have affected fertility. Rotation of males from pen to pen possibly would have helped overcome some of the low fertility encountered.

TABLE 3—Influence of floor space per bird on fertility in Beltsville Small White and Broad Breasted Bronze turkey breeder hens

Pen	Hens/toms housed	Square feet per bird	Fertile eggs			Percent fertility(*b*)	Percent hatch of total eggs
			Total	Per hen(*a*)	Per sq. ft.		
			A. Beltsville Small White				
2	30/2	2.36	570	19.0	8.1	39.7	28.3
3	25/2	2.67	815	32.6	26.3	70.2	50.3
4	20/2	3.07	832	41.6	26.8	82.1	62.0
5	15/2	4.36	594	39.6	9.1	69.6	57.4
			B. Broad Breasted Bronze				
12	20/2	2.27	142	7.1	3.1	14.2	7.2
11	15/2	2.88	532	25.5	12.3	72.5	55.3
18	9/1	5.80	298	33.1	5.7	73.8	44.6
9	9/1	6.59	299	33.2	4.5	58.7	35.6

(*a*) Based on number of hens housed.
(*b*) A significant difference was obtained between Beltsville Small White pens; however, no difference was shown between Broad Breasted Bronze pens.

Livability

Amount of floor space per bird did not appear to influence livability of hens used in this study (Table 2).

Statistical Discussion

The high incidence of floor eggs in some of the pens containing Broad Breasted Bronze turkeys rendered the analysis of variance technique useless in statistically analyzing the data from the pens. A statistical analysis of the average number of eggs set per hen and the average fertile eggs produced per hen was made using Linear Regression and showed that, in those pens, egg production per hen was influenced by floor space per bird, whereas fertility was not. The low fertility of the eggs produced in Pen 9 (Table 3) probably accounts for the finding of no influence of floor space on fertility. Since pens 9 and 18 were almost equal in the amount of floor space per bird, the lower fertility encountered in Pen 9 can possibly be attributed to the male in this pen.

An analysis of variance, using only the eggs laid in trapnests, of the data from the Beltsville Small White pens showed that, in those pens, number of eggs produced per hen did not depend on the floor space (Table 2) but that fertility did (Table 3).

GENERAL DISCUSSION

Since fertility decreased as floor space decreased, decreasing the amount of floor space below that usually recommended would be impractical where turkey breeder hens are kept under environmental conditions similar to the conditions of this study. Nevertheless, since decreasing the amount of floor space per bird to a point below present recommendations affected egg production to only a slight extent, this practice might become practical if steps could be taken to alleviate the lowered fertility experienced. Possible steps are as follows:

1. Rotating males from pen to pen.
2. Decreasing the ratio of females to males.
3. Using artificial insemination.
4. Increasing pen size but not amount of floor space per bird.
5. Holding feeding and watering space constant per bird rather than per pen.

Housing cost per turkey breeder hen can be decreased by allowing less floor space per bird; but the ability of a producer to cope with other management details will probably determine whether decreasing the amount of floor space per turkey breeder hen is profitable.

SUMMARY

In this experiment, number of eggs produced per hen tended to decrease in both the Beltsville Small White and Broad Breasted Bronze turkey breeder hens as the amount of floor space allowed per bird decreased; however, this effect was only slight.

Fertility, under the conditions of this study, tended to decrease in the Beltsville Small White turkeys as floor space per bird decreased. However, fertility in the Broad Breasted Bronze turkeys did not decrease as indicated by the statistical analysis, but this may have been due to the low fertility encountered in one of the single-male mated pens where a relatively large amount of floor space was allowed.

FROST PROTECTION BY WATER APPLICATION UNDER SIMULATED RADIATION FROST CONDITIONS

By R. B. BEAHM and E. H. KIDDER[1]

THE CONTINUOUS APPLICATION of a sufficient amount of water during a frost period is an effective means of protecting strawberry, pepper, tomato and bean plants against damage from radiation frosts. The heat given off as water turns to ice keeps the ice coated plant above its freezing temperature. A study was initiated at Michigan State University, East Lansing, Michigan, in a radiation frost chamber to determine the effect of several rates and frequencies of water application on the minimum air temperature that the plant could be protected against freezing damage.

Experimental Set-Up and Procedure

The experimental work was conducted in a rectangular refrigerated cabinet 18 inches wide, 16 inches deep and 28 inches high. The cabinet was insulated with 4 inches of styrofoam on the three walls, door and ceiling. The bottom of the cabinet was uninsulated and was provided with a heat source to prevent it from cooling below 32°F. The cabinet ceiling beneath the insulation was composed of a shallow metal enclosed pan in which methyl alcohol and dry ice were placed. The bottom of this pan was a refrigerating panel and acted as a radiation sink.

The surface temperature of the ceiling remained at a temperature of about-95°F. to establish approximately the same net radiant heat transfer from the bottom of the cabinet as occurs outdoors from the soil to the sky on a clear night. A frost scraper was provided to maintain an even thickness of frost on the ceiling. The floor of the cabinet was covered with dark soil. A heat sink was placed beneath the soil to maintain a constant soil temperature.

[1]Formerly graduate assistant and associate professor, respectively, department of agricultural engineering.

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The air temperature was controlled by varying the flow of air through the cabinet. The air in the cabinet was refrigerated by the ceiling cooling panel. The cabinet was operated inside of a 40°F. walk-in refrigerator; hence, the air supply for regulating the cabinet temperature entered the chamber at about 40°F. The cabinet air temperature could be varied from 15 to 32°F.

The plant material (young bean leaves) was supported on a thread net about 6 inches above the floor.

Water was sprayed into the cabinet at controlled rates and frequencies. The precipitation rate could be varied from 0.04 to 0.15 inches per hour. The frequency of application was varied from 20 to 120 seconds.

The air and plant temperature were measured with fine copper-constantan thermocouples. The temperatures were recorded on a 16-point, print-type potentiometer. A manual potentiometer was used for more precise measurements.

Experimental Procedure and Results

The test procedure was to place a leaf on the net and then allow the air in the cabinet to cool rapidly to the test temperature. This temperature was maintained for a period of about 2 hours. The leaf was examined at the end of the test for frost damage. If damage did not occur, succeeding tests were run at lower temperatures until a damaging temperature was reached for that frequency and rate of application. The safe temperature for frost protection was taken as 1°F. higher than the limiting test temperature.

The minimum temperature for frost protection for several spraying rates and frequencies is shown in Fig. 1. The 20-second spraying frequency afforded protection to about 2°F. lower temperature compared to the 2-minute spraying frequency at the same application rate. It appears that the same quantity of water applied more frequently in small doses results in this higher efficiency. At higher spraying frequencies, a higher percentage of the total water applied adheres to the leaf being protected; therefore, more heat is available when the water freezes. The horizontal position of the leaf in the cabinet tended to minimize runoff.

When the amount of water applied is just below that which is necessary to maintain a constant plant temperature, all of the water retained on the leaf freezes and there is a dry period before the next application of water is made. The plant temperature during this dry

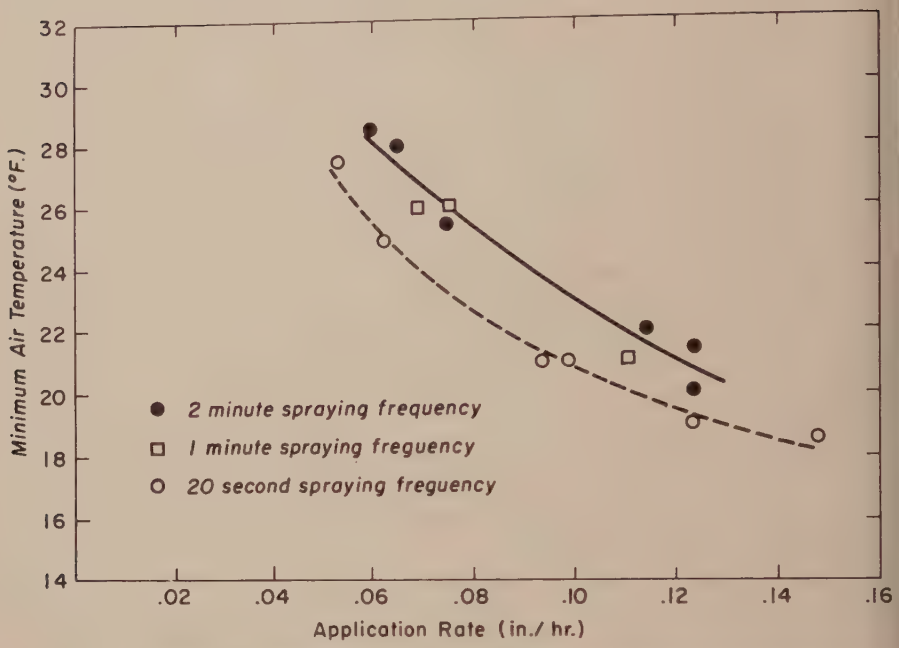

Fig. 1. Minimum temperature for frost protection versus water application rate.

period will be declining toward the temperature of the air. If this dry period is too long, the temperature of the plant could fall below its freezing level before another application of water was made.

Work was not done on finding out the effect of the ice mass. It became apparent during the tests that increasing the mass of ice from a frost protection standpoint was beneficial except for the physical damaging effect of too great an ice load on some plants.

The 20-second frequency curve in Fig. 1 indicates that the efficiency of application is greater at low application rates than it is at the higher rates. This appears reasonable as a greater runoff from the leaf would be expected at higher application rates.

Theoretical Frost Protection for Various Geometric Shapes

The flat plate, the sphere and the cylinder resemble the geometric configurations that would be seen in nature as an ice coat was built up on a leaf, bud, blossom or branch. Empirical heat transfer convection coefficients are available for these shapes. The following figures 2–5 represent simple heat balances. These heat balances are meaning-

ful to the frost protection field in that they relate minimum temperature for frost protection to water application rate.

Some assumptions had to be made in this analysis. The absolute value of the theoretical figures 2–5 could not be applied directly to a practical problem; however, a comparison of some of the theoretical developments to some of the experimental data showed reasonably close correlation. The calculation of figures 2–5 was based on a body temperature of 31½° F. The total heat loss from the body was the combined effect of radiation, convection and evaporation. The theoretical application rate in inches per hour for a 1-inch sphere at various wind speeds for protection against several air temperatures is shown in Fig. 2.

If an application rate of 0.1 inch per hour is chosen, an increase in the wind speed from 0.1 to 1.0 miles per hour increases the temperature at which protection would be obtained by six degrees (from 24°F. to 30°F.—Fig. 2). This sphere could be compared to an ice-coated bud. The effect of various diameter of sphere under conditions of varying temperature and application rate and a constant wind speed of 3 miles per hour is shown in Fig. 3. When the application rate is 0.10 inch per hour, a sphere ½-inch in diameter is protected

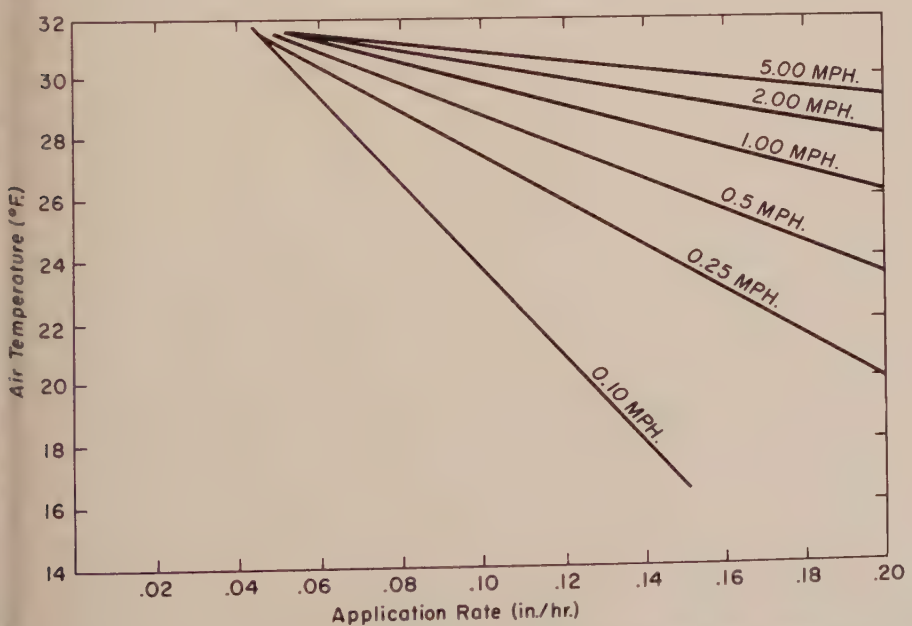

Fig. 2. Theoretical application rate for a 1-inch sphere at various wind speeds.

to 30°F. When a larger sphere of 2-inch diameter is used at an application rate of 0.10 inches per hour, the protected temperature is 28°F. (Fig. 3). Increasing the diameter from ½ to 2 inches has resulted in protection to a 2-degree lower temperature.

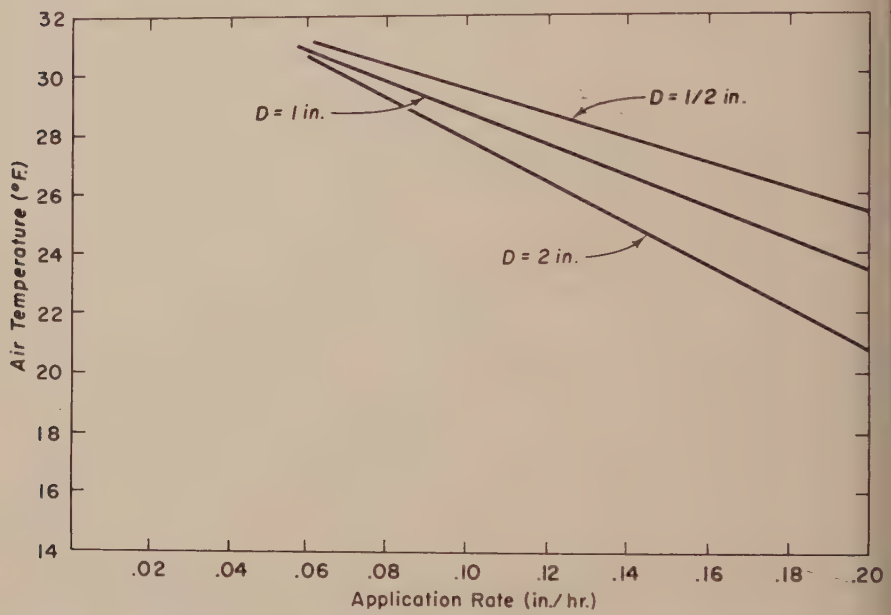

Fig. 3. Theoretical application rate for a sphere of various diameters at a constant wind speed of 3 miles per hour.

A comparison of the theoretical application rate under natural convection conditions for various shapes by various minimum protected temperatures is shown in Fig. 4. In order to protect against a minimum temperature of 20°F., an application rate of .06 inches per hour is required for a 1-inch horizontal plate. The rate must be 0.12 inches per hour for a 1-inch cylinder and 0.14 inches per hour for a 1-inch sphere. It appears that leaves would be protected by lower application rates than buds or stems.

The effect of a wind velocity 0.25 miles per hour and minimum protected temperature for various shapes and application rates is shown in Fig. 5. To protect against a minimum temperature of 20°F., the application rate for a 1-inch flat plate parallel to the wind must be 0.11 inches per hour; and the application rate for a 1-inch diameter sphere must be 0.20 inches per hour; and for a 1-inch cylinder the

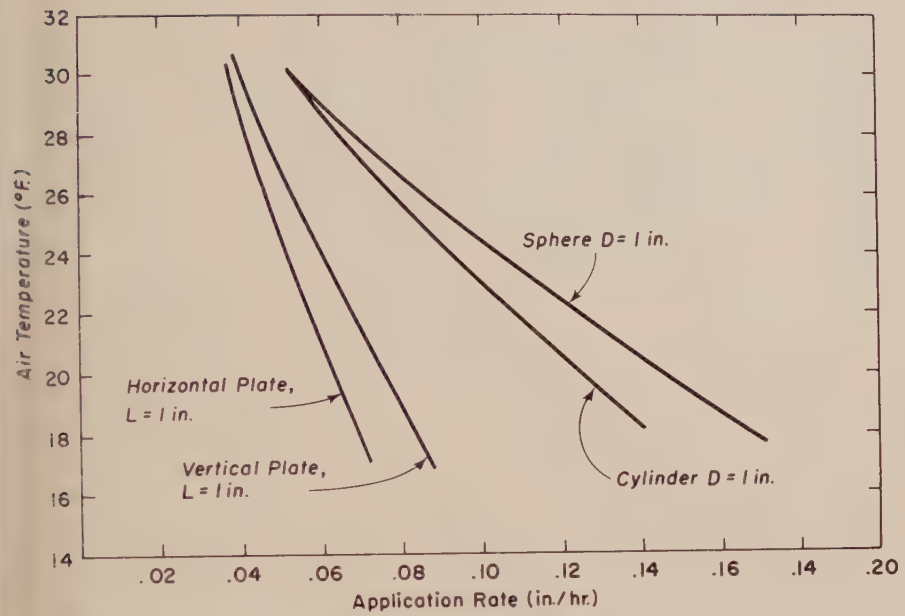

Fig. 4. Comparison of theoretical application rate under natural conditions for various shapes.

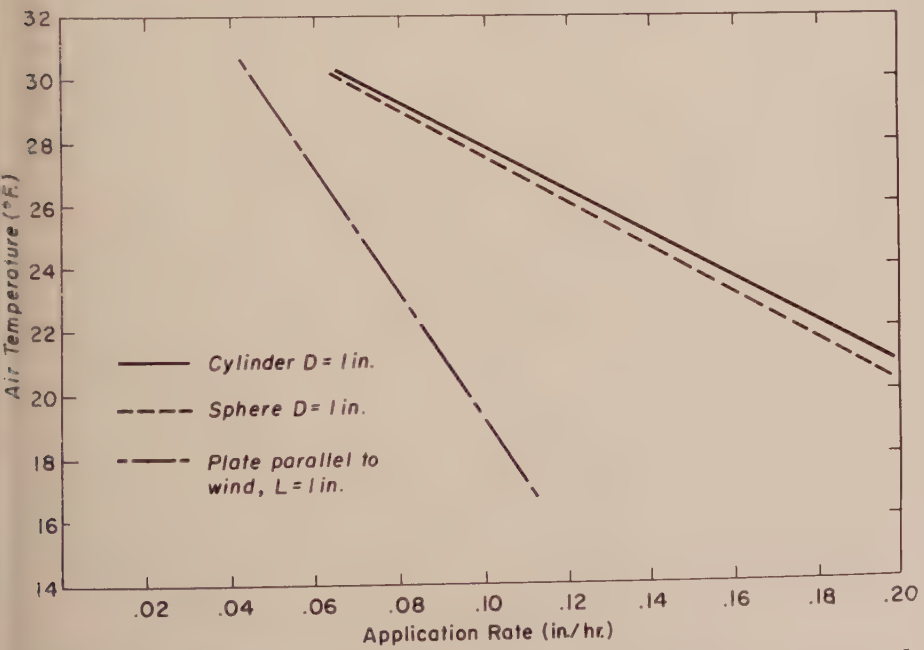

Fig. 5. Comparison of theoretical application for various shapes at a wind speed of 0.25 miles per hour.

rate must be 0.21 inches per hour. These are higher values than were reported in Fig. 4 and bring out the wind effects.

The effect of wind speed on frost damage to the edge and tip of leaves is of interest. There is a sharp increase in the film coefficient of convection heat transfer with an increase of velocity of air past the body. The local heat transfer coefficient is considerably greater at the leading edge of a flat plate than the average coefficient for the body as a whole. This helps to explain why the edges and tips of leaves are quite often the first part of the leaf to become damaged especially if there is any appreciable wind velocity.

THE CORRELATION BETWEEN LIVE MEAT TYPE SCORE, DRESSED SCORE AND MEAT YIELD OF BROILER CHICKENS

By EARL W. HENDERSON[1]

Poultry Science Department

Poultry producers have long recognized the demand for good table poultry and have bred strains and varieties of fowl which are more or less adapted for the purpose.

Discriminating housewives are interested in plump, tender meated birds which will yield a maximum of meat and a minimum of waste in the form of bones. Poultry processors are interested in birds which will yield the maximum of marketable meat in proportion to waste such as heads, feet, offal and/or feathers.

A maximum yield of marketable meat is an objective which may satisfy both food producers and processors but not necessarily the ultimate consumer. A high yield of edible meat is of direct economic value to consumers. Superior conformation of poultry, especially a broad thick meated breast, is closely related to yield of edible meat.

Poultry breeders, in order to continue to supply the demands of producers, processors and consumers must maintain high standards for growth and conformation of birds which will meet all requirements.

In order to improve conformation of poultry by breeding, criteria of live birds that can be estimated quickly and easily are needed. It is very easy to recognize desirable conformation in dressed fowl after the feathers have been removed but not so easy to recognize it in fully feathered live birds that are to be used for breeding.

Several conformation criteria have been developed in the industry for various purposes and with varying success. Many criteria are somewhat intangible and subject to variation in human judgment. Very few criteria are measureable in a precise physical sense. Criteria

[1]With technical assistance of Ed Farmer, technician, and Eino Niemala, farm foreman, of the poultry science department.

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which are measurable such as "shank length", "width of breast" or "breast angle" have variable prediction efficiencies in estimating a very important attribute, i.e. a high yield of edible meat in proportion to waste.

Meat Type Score Developed

The criteria for selection adopted in a meat-type breeding project[2] at this station in 1940 consisted of a relative "score" of five units, ranging from 1 (best) to 5 (poorest). Score No. 1 indicated the broad breasted conformation of the best specimens of the well known meaty Cornish breed. Score No. 5 indicated the rangy, angular breasted birds sometimes found among egg laying strains of such breeds as Rhode Island Red, Plymouth Rock, Minorca or Leghorn.

Efficiency of Meat Type Index

The relative efficiency of the "meat-type-score" criteria with live and dressed, mature roasting chickens, as an index of percentage of edible meat was determined at this station in 1946 (6). Later, in 1957 (2) the same type of test was made between the dressed score alone of small (5-7 week old) broilers and the percentage yield of edible meat and certain cooking qualities.

The breeding value of the criteria was demonstrated in 1956 (8) when a synthetic strain of chickens was established, 81 percent of which, scored "2" or better, and yielded a dressed meat percentage of 67-70 percent at 5-6 weeks.

Additional Evidence From Another Age Group

The following report is the result of a comparison of live scores of broilers (7-8 weeks of age) and the scores of the same birds after dressing and packaging. A multiple correlation comparison of live and dressed meat type scores with dressed and packaged weight was included. The data are summarized in Table 1.

OBJECTIVE

There were two specific objectives of the study reported herewith: one was to determine the correlation between live and dressed scores; the other was to compare packaged meat with the scores.

[2]Michigan Agricultural Experiment Station Project 266.

TABLE 1—Average percentage of marketable meat in relation to score categories

Meat type score	1	2	3	4	5	Totals
Number of chickens.....	40	53	31	6	None	130
Average percent meat...	75	73	72	71	—	73

MATERIALS AND METHODS

The materials available consisted of the pedigrees and meat yield records of two lots of chickens. One lot consisted of 121 crossbred chickens varying from superior to inferior meat type. Another lot consisted of 130, 7-8 week old chickens. All birds were progenies of several varieties of chickens varying from White Laced Red–Red Cornish crosses to Silver Cornish (7)–Red Leghorn crosses.

METHODS

Production methods included pedigree hatching. The pedigree process includes an individual numbered aluminum band inserted into the wing web of each chick. The chick retains the band for life and as long as necessary thereafter.

All chicks were hatched in the same incubator at approximately the same time of year. They were brooded in the same pen, and given access to identical all-mash feed mixtures, ad libitum. Live meat-type-scores were recorded at the same dates for each lot although the ages of each lot varied from 7-8 weeks. Selection for scoring, dressing and processing was at random in each lot except for the exclusion of obviously sick or crippled birds.

Previous experience with chicks of the ages selected, had indicated that variations in fat accumulations, which might possibly bias the meat type score, would be practically nil. Fat accumulations if present, could not affect the correlation between live and dressed scores. The dressed scores were recorded for indentical birds within a few weeks after processing, including quick freezing, and before variable shrinkage could have occurred.

Method of Scoring

The "meat type score" attribute of individual birds was estimated primarily by handling and spanning the breast for relative plumpness in proportion to size of birds.

More detailed descriptions of the method of the scoring system along with diagrams of prototypes may be found in references numbered 2, 5, 6 and 7.

RESULTS

Live weights varied from 660 grams to 972 grams. Dressed packaged yields varied from 62 to 82 percent.

A correlation of (.26 ± .09) between the live and dressed scores was obtained, which is highly significant statistically.

The average live score for 121 birds was (2.9) whereas the average dressed score of the identical lot of birds was (2.0). This confirms a previous finding that people tend to underestimate the dressed meat type score by approximately "1" score point when handling live birds.

The method of statistical analysis was the well known multiple correlation. The percentage yield of meat was the dependent and the live and dressed meat type scores were the independent variables.

This procedure determines the total relationship in percent between the meat-type-score categories and the yield of packaged meat, including giblets. It also makes it possible to determine the relative efficiency of the live and dressed scores as indices of meat yield.

The multiple regression equation ($X_1 = a - .30X_2 - 1.5X_3 \pm 10.75$) was highly significant. The dressed score criterion was most significant, as expected, and accounted for approximately 94 percent of the total correlation in yield of marketable meat. The live score criterion was confirmed by both the dressed score and percentage yield of marketable meat. The multiple correlation coefficient (R) was (.39) ± (.07).

CONCLUSION

The results of this experiment validate the use of the meat-type-score criteria as indices of yield in marketable meat and justify their use in breeding operations for the maintenance or improvement of conformation of market poultry.

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AN OBSERVATION OF FAT AND SOLIDS-NOT-FAT CONTENT IN HERD MILK

By R. C. LAMB and D. E. MADDEN
DEPARTMENT OF DAIRY
AND
J. R. BRUNNER and T. I. HEDRICK
DEPARTMENT OF FOOD SCIENCE

MICHIGAN LAW (8) requires that raw milk contain a minimum of 3.0 percent butterfat and 8.5 percent solids-not-fat (SNF) and that pasteurized bottled milk contain a minimum of 3.5 percent butterfat and 8.5 percent SNF. Dairymen have long been aware of the deviations from these standards in milk from individual cows. Several investigators (1, 2, 4) have reported population averages close to or even below these standards; others (3, 6) have found that many individual cows fall below the minimum standards.

The blending of substandard milk with the milk of other animals in the herd and the further blending of herd milk in the processing plant has been the practical solution to this problem. Conceivably, however, a concentration of herds producing substandard milk could necessitate either fortification of the milk or modification of legal composition requirements.

The recent study by Madden, Brunner, and Hedrick (7), in which the small Watson-pattern lactometer was used to measure the total solids content of herd milk, focused the attention on the relatively large number of herd samples that were substandard in solids-not-fat. The purpose of the present study was to examine the incidence of milk substandard in SNF and fat and to evaluate possible reasons for this occurrence.

EXPERIMENTAL PROCEDURE

Milk from 21 herds supplying a small dairy plant in Central Michigan was sampled twice per week from December 1957 to May

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1959. Each sample was a composite of two-days' production by the herd. A total of 2,597 samples were tested for fat, solids-not-fat (SNF) and protein. Butterfat measurements were made by the standard Babcock procedure, SNF measurements were made by the use of the small Watson-pattern lactometer (7, 14), and protein was measured by formol titration (10).

Herd size ranged from 15 to 70 milking cows. Fifteen of the herds were predominantly Holstein, three were Jersey, one was Brown Swiss, and two were composed of mixed breeds.

RESULTS

Fourteen of the 21 herds (66 percent) had three or more samples containing less than 3.5 percent butterfat. Only one herd had three or more samples containing less than 3.0 percent butterfat. Fifteen herds (71 percent) had three or more samples substandard for SNF

TABLE 1—Distribution of substandard milk and average composition of the milk by herds

Herd number	Percentage of substandard samples			Average composition			
	Fat		SNF	Fat	SNF	Protein	Breed
	(<3.0%)	(<3.5%)	(<8.5%)	(%)	(%)	(%)	
1	1	1	1	4.0	8.83	3.59	Mixed
2	0	1	1	4.1	9.08	3.77	Brown Swiss
3	0	10	53	3.7	8.48	3.30	Holstein
4	0	0	0	5.5	9.48	4.22	Jersey
5	0	18	18	3.6	8.60	3.24	Holstein
6	0	20	21	3.6	8.59	3.35	Holstein
7	1	27	50	3.5	8.52	3.29	Holstein
8	0	32	10	3.6	8.63	3.29	Holstein
9	0	5	43	3.8	8.55	3.26	Holstein
10	0	1	0	5.3	9.36	4.02	Jersey
11	5	74	100	3.3	7.84	3.10	Holstein
12	0	38	59	3.5	8.47	3.35	Holstein
13	1	1	1	5.1	9.25	3.99	Jersey
14	0	0	22	3.9	8.66	3.41	Holstein
15	1	12	4	3.7	8.69	3.37	Holstein
16	2	28	57	3.5	8.48	3.35	Holstein
17	0	16	18	3.6	8.61	3.27	Holstein
18	0	0	0	4.5	8.99	3.71	Mixed
19	0	28	39	3.6	8.52	3.28	Holstein
20	0	16	28	3.7	8.56	3.30	Holstein
21	0	23	34	3.6	8.52	3.24	Holstein
Overall	1	16	25	3.96	8.72	3.47	

(less than 8.5 percent SNF). Table 1 shows the distribution of substandard milk according to herds. The average content of fat, SNF, and protein for each herd for the entire experimental period is included in Table 1.

Out of 2,597 samples, 1,801 (69.4 percent) were normal for both fat and SNF, 147 (5.7 percent) contained less than 3.5 percent fat but were normal for SNF, 392 (15.1 percent) were substandard for SNF but normal for fat, and 257 (9.9 percent) contained less than 3.5 percent fat and 8.5 percent SNF. Thus 649 samples (25.0 percent) were substandard for SNF and 404 samples (15.6 percent) contained less than 3.5 percent fat. Only 13 samples (0.5 percent) contained less than 3.0 percent fat.

The relationship between fat and SNF was studied further by stratifying the data into eight fat levels. The range and average percentage of SNF and protein for each of these levels are shown in Table 2.

TABLE 2—Composition of milk by fat levels

Fat level	Average fat	Number samples	Percentage of samples	Average SNF	Range SNF	Average protein	Range protein
	(%)			(%)		(%)	
<3.0	2.51	13	0.5	8.15	7.45-8.79	3.47	2.89-4.30
3.0-3.4	3.33	391	15.1	8.39	7.25-8.87	3.27	2.16-4.64
3.5-3.9	3.67	1,418	54.6	8.58	7.19-11.13	3.32	2.66-4.43
4.0-4.4	4.17	262	10.1	8.84	8.17-9.54	3.57	3.00-4.48
4.5-4.9	4.70	173	6.7	9.10	8.54-9.43	3.79	3.07-4.56
5.0-5.4	5.22	182	7.0	9.36	8.89-9.66	4.08	3.33-4.70
5.5-5.9	5.64	147	5.7	9.48	9.16-9.82	4.16	3.27-4.76
≥6.0	6.02	11	0.4	9.59	9.40-9.83	4.29	3.77-4.74

Table 3 shows the average composition of the milk by breeds. There was a definite difference between breeds in average content of fat, SNF and protein in the milk. All of the breeds except Holstein averaged well above the minimum legal standards for fat and SNF.

The effect of season on the composition of milk is shown in Table 4. The percentage of butterfat in the milk was highest during the winter months of October through March, reaching its highest point in February and dropping to a low in June. The average percentage SNF was highest during the winter months, reaching a peak in January and a low point in July.

TABLE 3—Average composition of milk by breeds

Breed	Number samples	Percentage of samples	Average fat	Average SNF	Average protein
			(%)	(%)	(%)
Holstein	1,840	70.8	3.62	8.54	3.30
Jersey	410	15.8	5.30	9.36	4.08
Brown Swiss	78	3.0	4.06	9.08	3.77
Mixed	269	10.4	4.22	8.91	3.65

DISCUSSION

These results indicate that the producers have little difficulty in meeting the minimum butterfat standards. However, since bottled milk must contain a higher percentage of fat, the processor may find it necessary to blend or standardize the incoming herd milk in order to meet the minimum fat requirements, particularly if the major source of supply is from Holstein herds. Even in the case of Holsteins, careful blending of the herd milk should satisfy the minimum legal standards for butterfat.

The results of this study showed that a large portion (25 percent) of the herd milk was substandard in SNF content. Griffiths and Featherstone (4) reported a similar situation existing in Great Britain in which over 40 percent of the producers' bulk samples fell below 8.5 percent SNF.

TABLE 4—Average composition of milk by months

Month	Number samples	Percentage of samples	Average fat	Average SNF	Average protein
			(%)	(%)	(%)
January	258	9.9	4.07	8.80	3.49
February	222	8.6	4.09	8.79	3.47
March	292	11.2	4.03	8.72	3.43
April	284	10.9	3.99	8.68	3.44
May	222	8.6	3.88	8.72	3.52
June	188	7.2	3.73	8.71	3.52
July	188	7.2	3.76	8.58	3.42
August	163	6.3	3.76	8.63	3.37
September	176	6.8	3.92	8.70	3.48
October	171	6.6	4.08	8.81	3.63
November	137	5.3	4.03	8.73	3.50
December	296	11.4	4.05	8.74	3.46

A substandard SNF content in herd milk concerns not only the producer but the processor as well. The processor may be able to correct the deficiency by careful blending of the incoming milk supply. However, in a Holstein area this may not be feasible. The producer must find the causes for the low SNF level and then take the necessary steps to remedy them. The present data were not adequate to assign exact reasons for the milk being below standard for SNF, however, several possibilities were indicated: breed, heredity, season, feed mastitis, and adulteration.

Influence of Breed

A difference between breeds with respect to average levels of fat and SNF in the milk was shown. The breed averages in this study were in line with the voluminous published reports of breed averages for these constituents. Herds composed mainly of Holsteins were responsible for most of the substandard milk. However, not all of the milk from Holstein herds was below standard, suggesting that other factors are also involved.

Influence of Heredity

The evidence from breed data was indicative of a genetic difference in composition of the milk. Reported heritabilities of fat and SNF percentage range from .3 to .8 indicating that selection for fat or SNF percentage should be effective in changing the composition of the milk from our future dairy cows. This appears to have been happening over the past 50 years (1).

Selection for SNF percentage is greatly restricted by the lack of a program for SNF testing in the field. Until such a program becomes a reality, selection along these lines must continue to be on the basis of fat percentage.

This raises the question of the relationship between fat and SNF content. Richardson and Folger (9) reported that the relationship does not appear to be linear except within restricted limits of fat content. Other research (5, 6, 10, 12) has indicated a phenotypic correlation of .37 to .65 between fat and SNF percentages. The corresponding genetic correlations have been estimated as .35 to .72 (5, 10, 12). Von Krosigk (12) reported that the expected increase in SNF content after 19 years of selection based entirely on fat percentage would be .20, while the increase in the fat percentage would be .63.

Seasonal Variation

A seasonal effect on composition was evident. Milk produced during the winter months was higher in both fat and SNF content. The nature of the data precluded assigning causes for this trend; however, various investigators have reported that the most important causes of seasonal decline in the percentage of fat and SNF are high atmospheric temperature, high humidity, and poor quality feed.

Influence of Feed

Many authors have pointed out that improved feeding practices can cause an increase in fat and SNF content of milk. If the amount of starch or protein equivalent is increased up to the recommended energy intake level, it is reflected in an increase in the protein content of milk, thus increasing the SNF content.

Effect of Mastitis

It has been shown by Rowland and Zein-El-Dine (11) that the SNF content of milk may be considerably reduced by the presence of a mastitic condition of the udder. This drop in the SNF content is due almost entirely to a decreased lactose content. A low lactose content indicated that mastitis was important in a study of substandard herd milk in Scotland (2). The protein analysis data from the present study showed that most of the change in SNF content (Tables 2-4) could be accounted for on the basis of change in the protein content. This observation suggests that feeding has more effect than mastitis in substandard SNF percentage.

Adulteration

The addition of exogenous water to the milk supply remains as a final possibility to explain the high incidence of milk low in SNF content. Not only were all of the reported samples from one of the herds substandard for SNF, but 21 samples from this herd were eliminated from the study because the specific gravity was too low to measure with the lactometer.

Seventeen out of the 21 samples contained less than 3.0 percent fat, which adds to the suspicion of adulteration. All 21 samples were taken during the months of August through October, which is the normal base period in a grade A market and the logical time for a

producer to add water to the milk supply. The milk samples were not tested with a cryoscope to detect added water; therefore, the hypothesis of added water cannot be proven nor can the possible incidence of this practice be estimated.

Although blending of the herd milk resulted in a legal product, conceivably the resulting blend could require the addition of nonfat milk solids to bring the composition of the milk within legal limits. If such a situation results, a question arises as to the legality of the product. If these conditions are commonly encountered, a realistic look must be taken at the breeding, management, and related factors resulting in the production of substandard milk or legal standards must be re-defined to accommodate acceptance of such milk.

SUMMARY

Milk from 21 herds supplying a small dairy plant in Michigan was sampled twice per week for 18 months and tested for fat, SNF, and protein content. Out of 2,597 samples, 404 samples (15.8 percent) contained less than 3.5 percent fat, 13 samples (0.5 percent) contained less than 3.0 percent fat, and 649 (25.0 percent) were substandard for SNF (less than 8.5 percent SNF). Substandard fat content is not a problem but a substandard SNF content constitutes a problem for both the producer and the processor.

Several factors which may have had an influence on the SNF content have been discussed. These include breed, heredity, season, feeding, mastitis, and adulteration.

Although blending of the herd milk resulted in a legal product, conceivably a situation could arise in which it would not. The processor must then either add enough nonfat milk solids to reach the legal minimum level or sell a substandard product, both practices constituting illegal procedure. A more realistic look must be taken at the factors resulting in the production of substandard milk or legal standards must be re-defined to accommodate acceptance of such milk.

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PROGRESS AND PROBLEMS IN BREEDING PEAS RESISTANT TO ROOT ROTS[1]

By JOHN L. LOCKWOOD

Department of Botany and Plant Pathology

SUMMARY

Precise methods have been developed for evaluating pea seedlings for resistance to Aphanomyces and Fusarium root rots, and for production of zoospores of A. *euteiches* for inoculating plants. Of approximately 800 pea introductions tested for resistance to these diseases, several were incompletely resistant to Aphanomyces root rot, and many were moderately resistant to Fusarium root rot. None were immune to either disease. All commercial varieties were susceptible. Uniform lines of pea bearing seed of commercial type, and with resistance levels comparable to those in pea introductions, have been developed by breeding. Several problems bearing on the success of the breeding program are the incomplete resistance, particularly to *A. euteiches*, the possible existence of pathogenic races of the pathogens, and the probability that fungi other than the two considered are involved in the root rot complex.

INTRODUCTION

In 1956, a program of pea improvement was begun at Michigan State University with the aim of providing growers with better pea varieties, particularly with respect to disease resistance. Observations and surveys of pea fields since 1955 (9) have indicated that root diseases are the most important factor limiting pea yields and quality in Michigan. At the time of the initiation of the Michigan project, the Wisconsin, New York, and Minnesota Agricultural Experiment

[1]This paper reviews work done from 1956-1959 on a joint project of the department of botany and plant pathology and the department of horticulture. Disease work was the responsibility of J. L. Lockwood, and plant breeding that of J. C. Ballard.

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Stations had begun similar programs. However, only low levels of resistance had been found, and no root rot resistant varieties had been released.

Root rot of pea is a complex of several diseases of which the most important, in Michigan as well as in other states, appear to be Aphanomyces (*A. euteiches*) and Fusarium (*F. solani* f. *pisi*) root rots. Accordingly, the program was directed towards a) finding parent varieties resistant to these two diseases to be used in b) breeding root rot resistant varieties adapted to Michigan.

SOURCES OF RESISTANCE

A. euteiches and *F. solani* f. *pisi* were isolated from plants grown in Michigan, and their pathogenicity was repreatedly proven in inoculation experiments in the greenhouse. The pea collection of the USDA Plant Introduction Service, as well as many commercial varieties of pea, were evaluated in the greenhouse against these two fungi.

Work was first directed towards finding a source of resistance to Aphanomyces root rot, which was the most destructive of the root rot pathogens in greenhouse tests. A 20-seed lot of each pea variety was treated with sodium hypochlorite and planted in sand in pans which were placed in temperature tanks at 24° C (6, 8). The emerging seedlings were inoculated with a suspension of zoospores of *A. euteiches*. After 10 days, varieties were classified for disease by assigning ratings to the foliage (0-3), epicotyls (0-2) and roots (0-3). These ratings were totaled so that dead plants were rated 8.

Since high levels of resistance to this disease were not found, it became necessary to select plants with lower levels of resistance. This required increasing the uniformity of the disease in the testing procedure (7). Severe and uniform disease was produced when 4-6 day old seedlings from seeds planted 2 cm deep, and growing at 24°, were inoculated by pipetting 10 ml of a zoospore suspension containing 1.5 x 10^5 zoospores per ml as near the row as possible. It was essential to saturate the sand with water following inoculation. Even when the conditions were carefully standardized, variation in disease within and between tests could not be completely eliminated.

Inadequate production of zoospores for inoculating plants was sometimes a problem in spite of the use of many cultures. It was found that large numbers of zoospores (2-3 x 10^5 per ml) were produced when cultures were grown in maltose-peptone broth at 24-28°

for 5 days, then were transferred to tap water for 2 hours, and finally to 30-40 ml of distilled water (3, 4). Zoospore production could be further increased 2-4 times by aerating the distilled replacement water. The number of cultures required could thus be reduced to a fraction of that formerly needed.

The procedure used for evaluating resistance to Fusarium root rot was similar to that for Aphanomyces root rot. Disease was most severe when 4-day old seedlings from seeds planted 5 cm deep were grown at a temperature of 28° (unpublished results). A conidial suspension containing 2 x 10^5 per ml gave severe disease in about 18 days following inoculation. Saturation of sand following inoculation was essential for maximum development of Fusarium root rot. The method of rating disease severity was similar to that used for Aphanomyces root rot except that epicotyls were rated 0-3, hence killed plants had a disease index of 9.

Eight hundred and five pea introductions were evaluated for resistance to Aphanomyces root rot, and 793 were evaluated for resistance to Fusarium root rot (8). Several accessions were more resistant to Aphanomyces root rot than commercial varieties, but none were highly resistant or immune. Resistance to this disease was expressed primarily in the foliage which wilted less readily than that of more susceptible lines. In some cases, epicotyls were attacked less severely, but roots were nearly as badly decayed as those of commercial varieties. Higher levels of resistance to Fusarium root rot than to Aphanomyces root rot were found (8). None of the pea introductions was rated 0 (immune), but 69 were rated 1-3. Obvious resistance was expressed in roots and epicotyls. About 200 commercial varieties included in the pea introductions plus 35 additional varieties showed little or no resistance to these diseases.

Individual plants which appeared to be more highly resistant were sometimes found. Evaluation of progeny from such self-fertilized selections indicated that these were escapes rather than truly resistant individuals.

Several of the introductions resistant to Aphanomyces root rot in Table 1 were evaluated further (5). Resistance was expressed a) over a temperature range from 16-28°, b) in plants inoculated 0-21 days after seeding, and c) in seedlings inoculated with zoospore concentrations from 1 x 10^4 - 2.5 x 10^5 per ml. These results suggest that resistance, though low, would be expressed over a range of conditions and in older plants as well as seedlings.

TABLE 1—Average disease indices of pea introductions infected with Aphanomyces euteiches in greenhouse tests

P.I. number or variety	Average disease index(*a*)	P.I. number or variety	Average disease index(*a*)
166159	2.7	173059	5.7
167250	3.1	212916	5.8
180693	3.8	175232	6.0
169604 sel.	4.1	164669	6.3
184129	4.5	169604	6.9
180868	4.8	Miragreen	7.6
180702	5.2	Early Perfection	7.8

(*a*) Average disease index was based on 4-18 tests of 4 replications each. Disease index was based on a scale from 0-8, with 0 indicating healthy plants and 8, dead plants. LSD at 5% level for individual tests was 0.7-1.6.

Seed of P.I. 169604 selection, which is partially resistant to both Aphanomyces and Fusarium root rots, was planted for 2 years in root rot fields at several locations in Michigan (unpublished results.) Unfortunately, this variety showed little or no more field resistance to root rot than did commercial varieties. Possible reasons for the failure of P.I. 169604 selection to exhibit resistance are discussed in the section Problems and Outlook.

The seed and vines of most of the pea introductions, including the most resistant ones, were far from commercial type. Seeds were smooth (starchy) rather than wrinkled, and were often very small and hard. Seed coats were pigmented brown, purple, black, or were mottled, rather than green or transparent. In addition, seeds in the same lot were extremely variable with respect to seed size, color, and other characteristics.

BREEDING WORK

Breeding for resistance was begun in 1957 using pea introductions selected in greenhouse seedling tests as resistant parents. The introductions primarily used were 166159, 167250, 180693, and a selection of 169604. The commercial parents used were Alaska and Early Perfection, canning types, and Green-seeded Perfection, a freezing type of pea. These varieties are commonly grown in Michigan.

The breeding program used initially was one of inbreeding following the initial crosses between resistant parent and commercial variety. Resistant offspring were selected from segregating genera-

tions in the greenhouse. Because of the low level of resistance and the difficulty of selecting resistant individuals, inbreeding and selection were carried out for several generations before backcrossing to the commercial variety. With inbreeding and selection to the F_5-F_8 generations uniform lines were established with dwarf, intermediate, or tall foliage bearing green, wrinkled seed, and with resistance at a level equal to that of the resistant parent (Fig. 1). At present, several such lines are now in the F_6-F_9 generations. Some inbred lines have been backcrossed for 3-4 generations to commercial varieties.

Attempts were made to increase the level of resistance by crosses between different resistant parents. Thus far, however, no improvement in this respect has been seen in segregating generations.

Breeding for Fusarium root rot resistance proceeded in a similar manner. Introductions with the highest levels of resistance were crossed with the same three commercial varieties. The introductions most often used as resistant parents were 138945, 140165, and 174918. These three accessions generally had root rot ratings of 1 in seedling tests in the greenhouse. Some inbred lines now in the F_4-F_6 generations appear uniform for root rot resistance. A level of resistance equal to that of the resistant parent has been bred into plants producing green, wrinkled seed. Backcrossing to commercial types was begun during the winter 1959-1960.

The inheritance of resistance of P.I. 140165 was studied in crosses with Early Perfection (2). Resistance appeared to be dominant, possibly with several genes involved.

Breeding to combine Aphanomyces and Fusarium root rot resistances into single lines was also begun during the past winter.

PROBLEMS AND OUTLOOK

An important question in breeding peas resistant to root rots is whether the levels of resistance in the selected pea introductions are sufficiently high to be expressed under field conditions. This is difficult to determine since all fields probably contain a mixture of root rot pathogens, but there is evidence that some pea introductions express resistance to Fusarium root rot in the field (1). With respect to Aphanomyces root rot, this is even more difficult to determine in view of the lower levels of resistance available. The lack of field resistance shown by P.I. 169604 selection, which has partial resistance to Fusarium root rot as well as to Aphanomyces root rot, may be due

Fig. 1. Aphanomyces root rot in (left) resistant P.I. 169604 selection, (center) a resistant line developed from a cross between P.I. 169604 selection and Early Perfection, and (right) susceptible variety Miragreen. Resistant character from plants bearing smooth, dark colored seeds has been transferred by breeding to plants bearing wrinkled, green seeds. Note that resistance in P.I. 169604 selection and in line developed from the cross is not complete (roots and epicotyls show decay), but is superior to that of Miragreen (entire plant killed).

to insufficient resistance, but may also be due to the presence of different races of *A. euteiches* and *F. solani* f. *pisi*, or to pathogens other than the two considered in work so far.

At any rate, higher levels of resistance, particularly to Aphanomyces

root rot, would be desirable, and several possible approaches to this problem have been considered: a) continued evaluation of pea introductions as new ones become available, b) crossing different sources of resistance in the hope of increasing the level of resistance, c) inducing resistant mutants by the use of mutagenic agents such as ionizing radiation, d) crossing pea (*Pisum sativum*) with other legume genera resistant to *A. euteiches.*

The first two approaches have been continuing ones in our program. A beginning to the third approach, that of inducing mutants resistant to pea root rot, has been made (2, unpublished results). Exposure of seed of P.I. 169604 selection and Early Perfection to gamma radiation, produced no plants with high levels of resistance to Aphanomyces or Fusarium root rots, respectively, when several thousand seedlings from F_3 seed were evaluated. Probably, enormous numbers of seedlings will have to be evaluated because of the very low frequencies at which resistant mutants usually occur.

The fourth approach, that of intergeneric crossing, would seem to hold promise. Many introductions in the genera Lens, Cicer, Lathyrus, Vicia, and Astragalus were tested for resistance to Aphanomyces root rot (unpublished results). Highly resistant or immune lines were found in all these genera except Lens. Unfortunately, there is no record of successful crosses having been made between these genera and Pisum. Unsuccessful preliminary attempts to cross several commercial varieties with a highly resistant accession of Lathyrus were made during the winter of 1958-1959. Nevertheless, this approach seems worthy of continuation.

There is a possibility that pathogens other than the two so far considered are also of importance in the root rot complex. Pathogenic isolates of Rhizoctonia and Pythium were isolated early in the work, but they were isolated less frequently or caused less severe symptoms than *A. euteiches* and *F. solani* f. *pisi.* In the summer of 1959, *Thielaviopsis basicola,* a fungus important in root rots of other crops, tobacco in particular, was isolated from peas grown at East Lansing (unpublished results). Subsequently, this fungus was also isolated from peas grown in the greenhouse in root rot soil from three other Michigan locations. These isolates all produced root rot of peas in greenhouse tests. The symptoms resembled those caused by *F. solani* f. *pisi,* and the level of injury was similar to that caused by this fungus.

Thirty-five commercial varieties of peas and several pea introductions with resistance to Fusarium or Aphanomyces root rots were

evaluated in greenhouse tests for resistance to *T. basicola* last winter. None of the varieties was resistant. Commercial fields will be surveyed for this fungus during the 1960 season. The search for a source of resistance will be continued if this fungus is prevalent in Michigan pea fields.

The possibility that *T. basicola* or other fungi may be important in the root rot complex is supported by our experience with P.I. 169604 selection in field tests. This variety, with some resistance to both *A. euteiches* and *F. solani* f. *pisi* but susceptible to *T. basicola*, became severely diseased in fields, some of which are known to contain this fungus.

The possible existence of pathogenic races of the root rot fungi must also be considered. The discovery of new races would mean the need for additional sources of resistance in the breeding program. There is evidence that races may exist in *A. euteiches* (5). In inoculation studies with four isolates of this fungus, three gave a similar disease pattern on a series of pea introductions with different resistances, while a fourth gave a markedly different pattern of infection. Races in *F. solani* f. *pisi* have not been studied.

Solving the problem of pea root rot by developing resistant varieties is a difficult and complex task requiring continuing, long term effort by both plant pathologist and plant breeder. Indeed, for maximum resistance varieties of pea will have to be resistant to prevalent races of *A. euteiches* and *F. solani* as well as to any other important root pathogens. However, we may hope that the situation can be improved in the near future by the introduction of varieties resistant to single races of these two pathogens.

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THE GROWTH OF SUGAR BEETS IN SAND CULTURES FERTILIZED SOLELY WITH SEVERAL GREEN MANURES

By BURLEIGH C. WEBB, C. M. HARRISON, and S. T. DEXTER[1]

IT IS COMMON PRACTICE in humid regions to grow green manure crops which are plowed into the soil preceding the establishment of a cash crop. Many field experiments involving green manures have been conducted, and data obtained have indicated that benefits obtained from this practice arise through improvements in soil physical condition and the ability of the manure crops to supply nitrogen to the succeeding crop.

Data obtained from experiments (1), (3), (7) point up the rather transitory nature of the effects of green manuring on the physical properties of frequently tilled soils and the question relative to the direct contribution of green manures to the nutrition of the succeeding crops still remains.

Much of the work relevant to organic matter additions to the soil has dealt with the relationships between the chemical composition of the organic additions and their rate of decomposition. The investigations of Pinck et al (5), (6) and of Waksman (9) emphasize the effects of the carbon to nitrogen ratio in fresh organic matter on the rate of decomposition and nitrification.

According to Waksman (10), a definite relationship exists between the nitrogen content and cellulose decomposition. The work of Rege (8) represents one of the few reports dealing with the effects of easily available carbohydrate content of plant materials on their bio-chemical decomposition. Rege advanced the thesis that micro-organisms attacked nitrogenous plant tissues only after the more easily available carbohydrates had been depleted. Chang (2) found that the ratio of organic phosphorus to nitrogen was as significant to decomposition of plant materials as the ratio of carbon to nitrogen.

[1]Formerly graduate student, Michigan State University, now Associate Professor of Agronomy, Tuskegee Institute, and Professors of Farm Crops, Michigan State University, respectively.

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This investigation was designed to study the fertility value of several crops used as green manure. Specifically, the objective of this study was to determine nitrogen recovery and dry matter productions of sugar beets fertilized solely with plant materials obtained from the several crops. The relationship of the easily available carbohydrate content of the plant materials to their manurial efficiency was also determined.

EXPERIMENTAL PROCEDURE

Plants composing three crop series, designated in Table 1, were grown from seed in the greenhouse in sand cultures and fed either Shive's R_2S_5 nutrient solution or this solution modified for minus nitrogen treatments. A control treatment was provided in which the plants were supplied with tap water only. All treatments occurred in six replicates set up in a randomized block design. All plants were harvested when the vetch had reached the early flowering stage.

The root and top growth was dried at 70°C. for 16 hours in a forced air oven and ground in a Wiley mill to pass a 20-mesh sieve. A dry matter sample sufficiently large for chemical determinations was taken from each culture and reserved for analysis of easily available carbohydrates (total sugars and starch) and total nitrogen content.

TABLE 1—Average dry weight yield in grams of green manures per culture at time of harvest; all legume seeds were inoculated

Crop series(*a*)	Nutrient treatments		
	NPK	PK	Check
	gms.	gms.	gms.
Alfalfa and grass			
Alfalfa	11.8	12.2	1.7
Alfalfa-B.G.	23.2	13.6	3.3
Bromegrass	22.5	5.1	1.7
Ladino clover and grass			
Ladino clover	19.1	16.4	1.6
Ladino clover-O.G.	29.0	17.3	3.5
Orchard grass	32.1	7.9	2.1
Vetch and rye			
Hairy vetch	34.6	31.4	9.8
Hairy vetch-rye	38.3	39.4	6.7
Rye	30.1	8.3	5.3

Difference at 5% level required for significance between mean dry weights of cultures which received NPK and PK treatments is 4.86.

(*a*) B.G. = Bromegrass; O.G. = Orchardgrass.

Duplicate determinations were made when the dry matter yield was large. The plant material remaining from the cultures of each treatment was composited, appropriately divided, and used as the sole source of applied nutrients in clean sand. Fifteen kilos of sand were placed in each pot and the green manure added. The quantity of green manure added to each culture varied with the dry matter produced by the green manure plants grown under the various nutrient treatments, thus providing a wide range of added nitrogen from different plant sources. (See Table 3).

Following a 2-week incubation period of the manures in damp sand, three 10-day-old sugar beet seedlings were transplanted to each pot. The manurial treatments occurred in triplicate and were set up in the greenhouse. The control treatment, where beet seedlings were transplanted to clean sand to which manures were not added, occurred in six replicates.

Dry matter yields of the root and top growth of sugar beets were determined after 92 days of growth. The material harvested from each culture was analyzed for total nitrogen, and the percent nitrogen recovered from added manures was ascertained. Total nitrogen was determined by the A.O.A.C. (1940) method of Kjeldahl, modified to include nitrates. Total sugar was determined by the method of A.O.A.C. and Munson-Walker tables were used for the conversion of sugar values to invert sugar. Total starch was determined by a procedure resulting from a collaborative study by A.O.A.C. and was based upon the report of Hoffpauir (4).

RESULTS AND DISCUSSION

Yield and composition of green manures.

The average dry weight yields of the green manures are presented in Table 1. The decreasing order of dry matter yield occurred as follows: (Legumes) vetch, Ladino clover, alfalfa; (mixtures) vetch and rye, Ladino clover and orchardgrass, alfalfa and bromegrass; and (grasses) orchardgrass, rye, and bromegrass. Within a particular crop series, the average dry matter yield per culture to which nitrogen was applied was usually higher than that obtained from cultures that received the PK treatment or which received only tap water, particularly in the absence of legumes.

The relationship between the percent easily available carbohydrates and percent total nitrogen in green manure material is pre-

sented in Table 2. In contrast to the rank of the crops in dry matter production, it was found that on the basis of the percent easily available carbohydrates, the crop series ranked in the following order: Alfalfa and grass, Ladino clover and grass, and vetch and rye. Within a particular crop series, plants that received the PK treatment usually had a higher percentage of easily available carbohydrate than those receiving the NPK treatment.

TABLE 2—Carbohydrate-nitrogen relationships in green manure plants at time of harvest, dry weight basis

Crop series	Percent easily available carbohydrate			Percent total nitrogen			Ratio of easily available carbohydrate to total nitrogen		
	Nutrient treatment								
	NPK	PK	CK	NPK	PK	CK	NPK	PK	CK
Alfalfa and grass									
Alfalfa	10.5	13.1	6.9	3.3	3.0	3.2	3.1	4.4	2.2
Alfalfa-B.G.	4.6	10.7	10.1	2.9	2.8	1.5	1.6	3.8	6.6
Bromegrass	3.9	9.3	12.0	2.7	0.7	1.2	1.4	13.1	10.2
Ladino clover and grass									
Ladino clover	5.1	5.3	5.7	3.5	3.0	2.0	1.5	1.8	2.8
Ladino clover-O.G.	3.0	5.4	6.4	2.7	1.9	1.5	1.1	2.8	4.3
Orchardgrass	2.9	5.4	5.3	2.7	0.6	1.4	1.1	9.3	3.9
Vetch and rye									
Vetch	3.2	3.2	1.2	3.2	3.2	2.4	1.0	1.0	0.5
Vetch-rye	4.3	3.7	4.6	2.6	2.5	1.7	1.7	1.5	2.7
Rye	2.9	7.5	6.9	2.4	0.8	0.8	1.2	9.9	8.6

The three legume species contained approximately equal percentages of nitrogen when they were fed either Shive's complete solution or Shive's solution minus nitrogen, independent of the dry matter yield. On the other hand, the larger dry weight of each grass was associated with a higher percent of nitrogen. The percent total nitrogen was slightly lower in the plants of the mixed cultures than in the legumes grown alone, probably due to the presence of the included grass species. The percent total nitrogen was extremely low in the grass species grown alone and without applied nitrogen.

Manurial efficiency, yield and nitrogen recovery in sugar beets.

Under the conditions of this experiment, there was considerable difference in the growth and nitrogen content of the green manures.

(It is not suggested that these differences are likely to be duplicated under any other conditions.) Table 2 shows that the percentages of nitrogen in these green manures varied widely—from 0.6 to 3.5 percent—thus giving a well distributed cross section of composition for green manures. Similarly, it is indicated in Table 3 that widely differing amounts of green manure were added, not only with the various species, but also between species and mixtures of species—providing

TABLE 3—Manurial efficiency, average dry matter yield per culture and nitrogen recovered in sugar beets grown in clean sand and fertilized only with the various green manures

Manurial treatments			Dry matter yield of sugar beets	Nitrogen recovered in beets(a)		Manurial efficiency
Crop series as manure	Manure added	Nitrogen added				
	g.	mg.	g.	mg.	%	%
Manures previously grown with complete nutrient solution (NPK)						
Alfalfa and grass						
Alfalfa	10.7	353.1	10.4	101.3	28.7	25.8
Alfalfa-bromegrass	13.1	379.9	12.1	112.9	29.7	28.4
Bromegrass	15.1	407.7	16.7	147.3	36.1	37.8
Ladino clover and grass						
Ladino clover	12.3	430.5	17.1	190.6	44.3	36.7
Ladino clover-orchardgrass	19.3	421.1	20.1	201.7	38.7	36.1
Orchardgrass	22.0	594.0	24.7	262.7	44.2	39.4
Vetch and rye						
Vetch	23.5	752.0	24.6	202.5	26.9	31.0
Vetch-rye	22.6	587.6	22.2	193.9	33.0	35.6
Rye	20.7	496.8	19.1	158.1	31.8	35.8
Manures previously grown with minus nitrogen solution (PK)						
Alfalfa and grass						
Alfalfa	8.0	240.0	6.2	58.6	24.4	20.4
Alfalfa-bromegrass	7.6	212.8	4.0	24.2	11.4	12.7
Bromegrass	3.6	25.2	0.7	−10.5	−41.7	−23.8
Ladino clover and grass						
Ladino clover	11.2	336.0	4.9	43.8	13.0	10.7
Ladino clover-orchardgrass	10.4	197.6	5.1	34.7	17.6	19.2
Orchardgrass	5.2	31.2	1.1	−6.5	−20.8	−6.4
Vetch and rye						
Vetch	22.3	713.6	24.1	253.3	35.5	30.7
Vetch-rye	25.8	645.0	23.9	229.6	35.6	35.0
Rye	7.8	62.4	2.6	14.7	23.6	20.8

TABLE 3—Concluded

Crop series as manure	Manurial treatments: Manure added	Manurial treatments: Nitrogen added	Dry matter yield of sugar beets	Nitrogen recovered in beets(*a*)		Manurial efficiency
	g.	mg.	g.	mg.	%	%
Manure previously grown with tap water only (Check)						
Alfalfa and grass						
Alfalfa	0.5	16.0	0.8	−10.9	−68.1	−31.3
Alfalfa-bromegrass	2.1	31.5	1.6	0.2	0.6	9.5
Bromegrass	1.2	14.4	0.6	−11.6	−80.6	−48.7
Ladino clover and grass						
Ladino clover	1.1	22.0	0.5	−15.0	−68.2	−36.4
Ladino clover-orchardgrass	2.3	34.5	2.1	8.6	24.9	23.2
Orchardgrass	1.3	18.2	0.5	−14.4	−79.1	−44.0
Vetch and rye						
Vetch	4.7	112.8	2.1	8.0	7.1	7.1
Vetch-rye	6.4	108.8	3.1	30.0	27.6	16.5
Rye	3.6	28.8	1.3	1.9	6.6	0
Control	...	....	1.3	21.4	....	....

(*a*) Nitrogen recovered = mg. nitrogen content of beets fertilized with manure minus mg. nitrogen content of the control; nitrogen recovered pct. = $\frac{\text{mg. "nitrogen recovered" x 100}}{\text{mg. nitrogen in green manure}}$

Manurial efficiency = $\frac{\text{Milligrams of dry matter in beets in excess of the control}}{\text{Milligrams of nitrogen added as manure}}$

a wide cross section of quantity as well as quality (nitrogen content) of the added green manure. In this experiment, it will be observed that the dry matter yields and total nitrogen content of the beets varied widely, both within and between species of green manure.

The percentage of nitrogen that was recovered by the sugar beets was generally greatest, from any one species or mixture, when the larger amounts of nitrogen were applied. In many cases, and especially when grasses alone were used, this resulted when nitrogen was used in growing the grasses. However, over the entire range of quantities of organic matter and of nitrogen used, with six species in various combinations, a positive correlation of 0.973 was obtained between quantity of nitrogen applied as manure and dry matter yield of beets, and 0.979 between quantity of nitrogen applied and quantity recovered.

Thus, manurial efficiency, in terms of sugar beet production of dry matter per unit of nitrogen added in green manure, was not appreciably

affected either by species, or quantity, except as these affected the total nitrogen added in the green manure. The use of very small amounts of green manure, containing very small amounts of nitrogen, (1.1 mg. or less)regularly led to a negative recovery of nitrogen. This occurred, moreover, whether the green manure was alfalfa and Ladino clover, containing high percentages of nitrogen, or orchard and bromegrass containing low percentages of nitrogen. Such consistency, over the entire range, is responsible for the high correlations above.

No significant correlations were found between the easily available carbohydrate content or the carbohydrate-nitrogen ratios of the manures and dry matter yield of beets, manurial efficiency, or nitrogen recovery. The more important characteristics of the plant materials used as green manures were closely related to the quantities of the manures produced and their nitrogen content.

SUMMARY

Green manuring crops—alfalfa, smooth bromegrass, Ladino clover, orchard grass, hairy vetch and rye,—were grown in sand cultures with NPK and PK fertilization (Shive's R_2S_5 solution). A control received tap water only.

Oven-dried material from these crops was analyzed for total nitrogen and for readily soluble carbohydrates. Weighed amounts were used as the sole supply of fertilizer in sand cultures of sugar beets. All were grown in the greenhouse.

The production of dry matter and the total nitrogen content of the sugar beets was determined. From these figures, the recovery of nitrogen added in the green manure and the production of dry matter per gram of added nitrogen was computed.

The dry matter yield and the total nitrogen content of the beets was strictly determined by the amount of nitrogen added by the green manures. Species source or fertilizer treatment of the green manures had no effect on the growth of the beets except as it affected the amounts and the nitrogen content of the green manures. The content of readily soluble carbohydrates had no relationship to the manurial efficiency of the green manures.

The data reported here suggest that the manurial efficiency of bromegrass, orchardgrass, or rye, grown alone or in association with the appropriate legume, is equal to that of the legume provided the grasses are grown with adequate nitrogen.

In this greenhouse experiment with sand cultures, the plant species and mixtures used as green manure—vetch, vetch and rye, rye, Ladino clover, Ladino clover and orchardgrass, orchardgrass, alfalfa, alfalfa and bromegrass, and bromegrass—appeared to be of equal quality provided that the amount of total nitrogen added was similar.

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AN ANALYSIS OF A TWO-SPECIES THREE-LAYER WOOD FLAKE BOARD

By OTTO SUCHSLAND

Department of Forest Products

In the last decade, the particle board industry has become one of the major wood using industries. A flake board is a special type of particle board, composed of regularly shaped thin wooden flakes rather than irregularly shaped particles.

Despite considerable refinement, a general theory of the process is still missing. The following paper is an attempt to provide a theoretical basis for the design of three-layer flake boards.

It is hoped that the experimental results obtained from using a combination of two Michigan hardwoods will encourage further study leading to the development of particle board manufacture in Michigan.

Introduction

A three-layer flake board can undoubtedly be classified as a sandwich panel, according to the ASTM definition of structural sandwich construction:

"A laminar construction comprising a combination of alternating dissimilar simple or composite materials assembled and intimately fixed in relation to each other so as to use the properties of each to attain specific structural advantages for the whole assembly."

Such a sandwich construction usually is the result of a laminating process, by which the individual layers, selected with regard to their properties according to certain design principles, are intimately fixed in relation to each other. The properties of the whole assembly can be predetermined if the properties of the individual layers as well as their thickness ratios are known. This design method is based on the assumption that the properties of each individual layer are the

ARTICLE 43–40

same before and after assembly. In most cases, of course, the laminating process has no effect on either the properties of the laminas or their thickness ratios, and this assumption is valid.

In the case of a three-layer flake board, however, the manufacture of the laminas and their assembly are combined in one process.

The final properties of each individual layer are composite functions of raw material variables and variables of the laminating process. Whereas the raw material variables can be selected at will for each layer, the variables of the laminating process, which shall be combined here under the term "press cycle", are the same for all layers.

The following study is an analysis of a two-species, three-layer flake board at an overall density of 0.700 g/cm³. It demonstrates the interrelationship between certain raw material variables, press cycle, and elastic-mechanical properties.

The Manufacture of Three-Layer Flake Boards

Most properties of a one-layer flake board are functions of the board density. These functions are dependent upon raw material variables like species, flake geometry and resin content and can be established for any combination of these variables. For given raw materials, the board properties can, therefore, be easily controlled by controlling the board density S:

$$(1) \quad S = \frac{W}{A\ T}$$

where W = Weight of flakes
A = Press area
T = Board thickness

Similarily, the properties of the individual layers of a three-layer flake board are functions of their densities. Equation (2) states the relation between layer densities and overall density:

$$(2) \quad S_{res} = \frac{W_c + W_f}{A\ T} = S_c\,(1-\lambda) + S_f\lambda$$

where W_c = Weight of core flakes
W_f = Weight of face flakes
S_c = Core density
S_f = Face density

$$\lambda = \text{Shelling ratio} = \frac{\text{Face thickness}}{\text{Total thickness}}$$

S_{res} = Overall board density

However, S_c and S_f cannot be controlled directly.

If for example S_{res} and T are to be held constant, S_c, S_f and λ will depend on the weight ratio $\frac{W_c}{W_f}$ and the respective compressibilities of face and core material under conditions developing in the press. $\frac{W_c}{W_f}$ can easily be controlled. The control of λ, however, is more difficult since the compressibility of the individual layers is not only a function of species and flake geometry but also a function of the instantaneously changing moisture content and temperature of the material during the period of pressure application. The most severe of all combinations of moisture content and temperature occurring during the effective part of the press cycle will determine the compression rates of core and face materials. The length of the effective press cycle—that is, the time required to compress the mat to the thickness of the spacers—is, therefore, an important factor affecting λ and thereby, S_c and S_f. After the spacers have been reached, the deflection of the mat stops, the pressure is indeterminate and λ will not change appreciably during the rest of the press cycle. The variation of the temperature of the press platens is generally limited to a small range satisfying the requirements of the adhesive used and at the same time avoiding precuring.

It can be concluded that for a given overall density S_{res} and a given overall thickness T, S_c, S_f and λ can be controlled only indirectly by varying the following factors:

1. Raw material variables affecting the compressibility: Species, flake geometry, initial moisture content.
2. Weight ratio $\frac{W_c}{W_f}$.
3. Initial pressure, affecting the length of the effective press cycle.

The Selection of Raw Material Variables

One of the most important characteristics of a sandwich panel is its remarkable stiffness. The stiffness of a sandwich bending specimen is proportional to its equivalent modulus of elasticity:

$$(3)\quad D = E_e I$$

where D = Stiffness
E_e = Equivalent modulus of elasticity in bending.
I = Moment of inertia

For a sandwich beam of symmetrical cross section and identical face material on both sides:

(4) $E_e = E_f - (1-\lambda)^3 (E_f - E_c)$ (See footnotes 2 and 3)

where E_f = Modulus of elasticity of faces
E_c = Modulus of elasticity of core
λ = Shelling ratio

In order to obtain a high stiffness D, the raw material variables must be so selected that E_f is as high as possible.

This can be realized by either one or by a combination of two or more of the techniques listed under a, b, c, d, in Table 1.

TABLE 1—Techniques used to achieve sandwich effect in three-layer flake boards

Technique	Different species	Different flake geometry	Different moisture content	Different resin content
a				x
b			x	
c		x		
d	x			
e	x	x	x	x

Method a will create a sandwich effect by merely reinforcing the face material with a higher resin content.

Method b aims at an increased compressibility of the face material which will result in an increased face density.

Method c accomplishes the same by using thinner, wider flakes for the faces and thicker narrower flakes for the core[3].

Method d finally (although not being used commercially) would create a difference in the compressibilities of core and faces by using a heavier species of high compression strength

[1] Curry, W. T. (1955). Laminated beams from two species of timber. H. M. Stationery Office, London.

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[3] Suchsland, O. (1959). An analysis of the particle board process. Mich. Agr. Expt. Sta. Quart. Bul. 42:2, pp 350 - 372.

for the core flakes and a lighter species of low compression strength for the face flakes. The resulting difference between core and face density would probably not be as great as in boards made according to techniques b and c, the compression ratio of the faces, however, could be high enough to result in a strong sandwich panel at a moderate overall density.

The technique used for the three-layer board described in this study is indicated under *e* in Table 1. A more detailed list of the raw material variables is given in Table 2.

TABLE 2—List of raw material variables used for two-species three-layer flake board

	Core	Faces
Species	Elm: density .669 g/cm^3	Aspen: density .456 g/cm^3
Flake geometry	Length: 0.542 ± 0.042 in. Width: 0.035··*0.038*··0.042 in. Thickness: 0.013 ± 0.0003 in.	Length: 0.456 ± 0.016 in. Width: 0.053··*0.058*··0.064 in. Thickness: 0.006 ± 0.0003 in.
Moisture content	6%	6% and 12%
Resin content, urea formaldehyde	6%	12%

All flakes were cut from 1-inch thick boards on a disc-cutter and then further reduced by hammer milling through a ¾-inch screen. The distribution of the flake widths, the dimension showing the largest variation is shown in Fig. 1. The deviation from a straight line at small flake widths indicates some breakdown in length.

Weight Ratios and Press Cycle

Without consideration of the economical limitations, three weight ratios were selected which were expected to result in a broad range of shelling ratios (Table 3). All weight ratios were restricted by the condition:

$$S_{res} = \frac{W_c + W_f}{A\ T} = 0.700\ g/cm^3$$

The boards were manufactured in a 20 x 20 in^2 hot press using steel spacers of ⅜-inch thickness. The length of the effective press

cycle, i.e., the closing time, could be controlled reasonably well by the initial pressure. Initial pressure of 250 p.s.i. resulted in a closing time of 1.5 min. for all raw material combinations and weight ratios, and under an initial pressure of 500 p.s.i., the closing time was reduced to 0.5 min. Total press time was 15 min. and platen temperature was maintained at 325°F. for all boards.

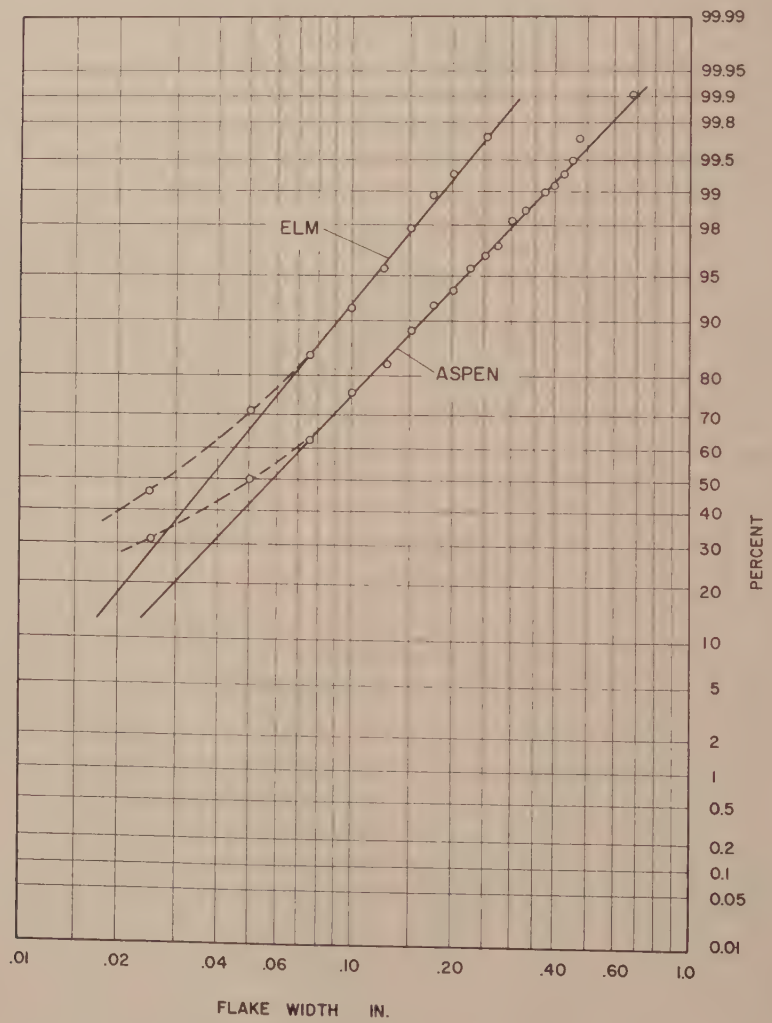


Fig. 1. Distribution of flake width of core and face material.

N = 278 (Elm)
N = 526 (Aspen)

TABLE 3—Design of experiment

Weight ratio $\frac{W_c}{W_f}$	$\frac{750\text{ g.}}{500\text{ g.}}=1.50$				$\frac{850\text{ g.}}{400\text{ g.}}=2.13$				$\frac{950\text{ g.}}{300\text{ g.}}=3.16$			
Moisture content of face material	6%		12%		6%		12%		6%		12%	
Closing time (minutes)	0.5	1.5	0.5	1.5	0.5	1.5	0.5	1.5	0.5	1.5	0.5	1.5
Replications(*a*)	4 boards	4 boards	4 boards	4 boards	4 boards	4 boards	4 boards	4 boards	4 boards	4 boards	4 boards	4 boards

(*a*) Each board yielded 4 standard bending test specimens, 2 standard shear test specimens and 2 standard tensile test specimens.

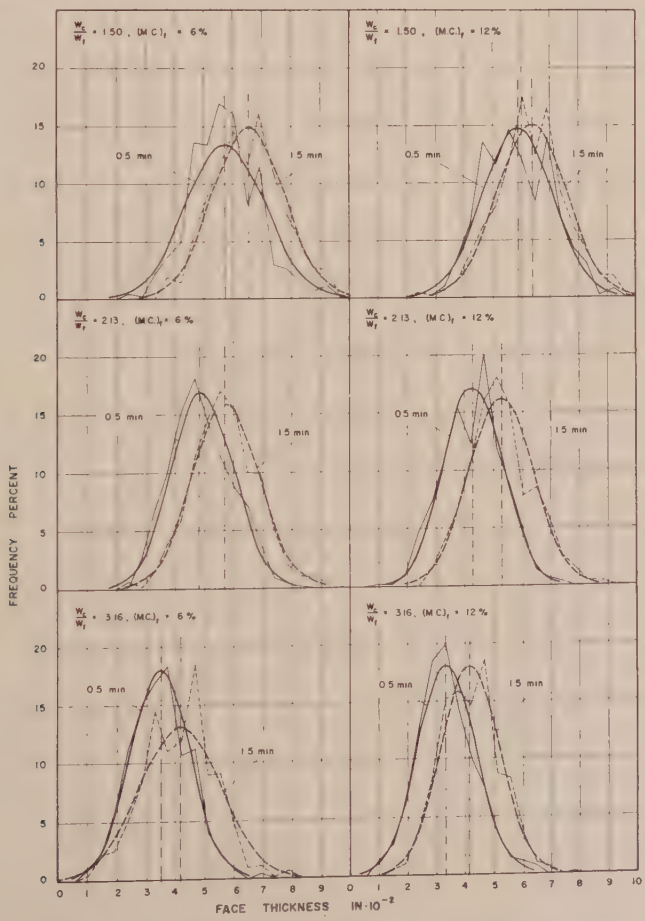
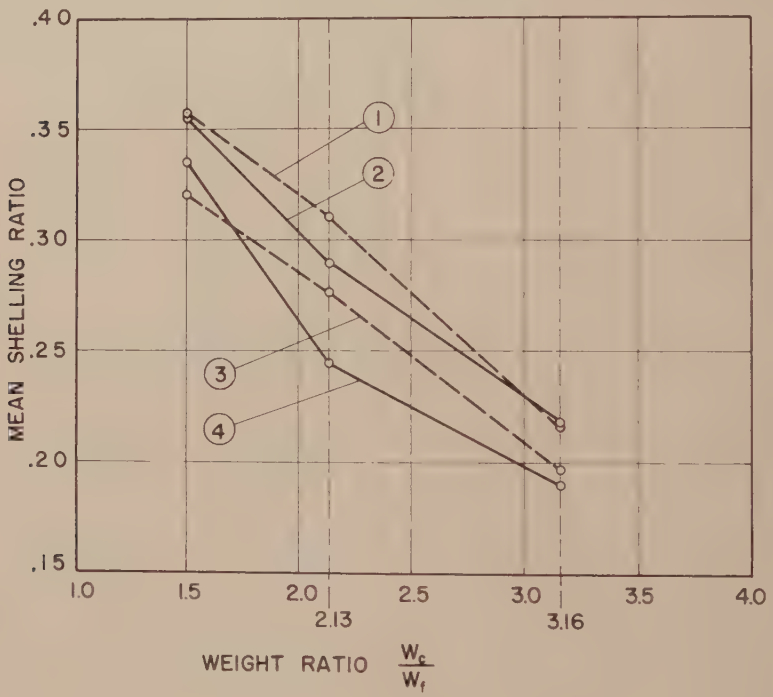

$\frac{W_c}{W_f}$ = 1.50, (M.C.)$_f$ = 6%
$\frac{W_c}{W_f}$ = 1.50, (M.C.)$_f$ = 12%
$\frac{W_c}{W_f}$ = 2.13, (M.C.)$_f$ = 6%
$\frac{W_c}{W_f}$ = 2.13, (M.C.)$_f$ = 12%
$\frac{W_c}{W_f}$ = 3.16, (M.C.)$_f$ = 6%
$\frac{W_c}{W_f}$ = 3.16, (M.C.)$_f$ = 12%
0.5 min
1.5 min
FREQUENCY PERCENT
FACE THICKNESS IN·10^{-2}

Fig. 2. Distribution of face thickness. Nominal overall thickness = 0.375 in. N = 448 (each distribution).

Shelling Ratios and Layer Densities

In order to analyze the effect of raw material and process variables on the final properties of the board, shelling ratio, core density and face density had to be determined.

Both face thicknesses were measured on all bending specimens. Their distribution and the computed mean shelling ratios are shown in Fig. 2 and Fig. 3. Figure 2 clearly demonstrates the remarkable uniformity of the handfelting technique. After determining the over-



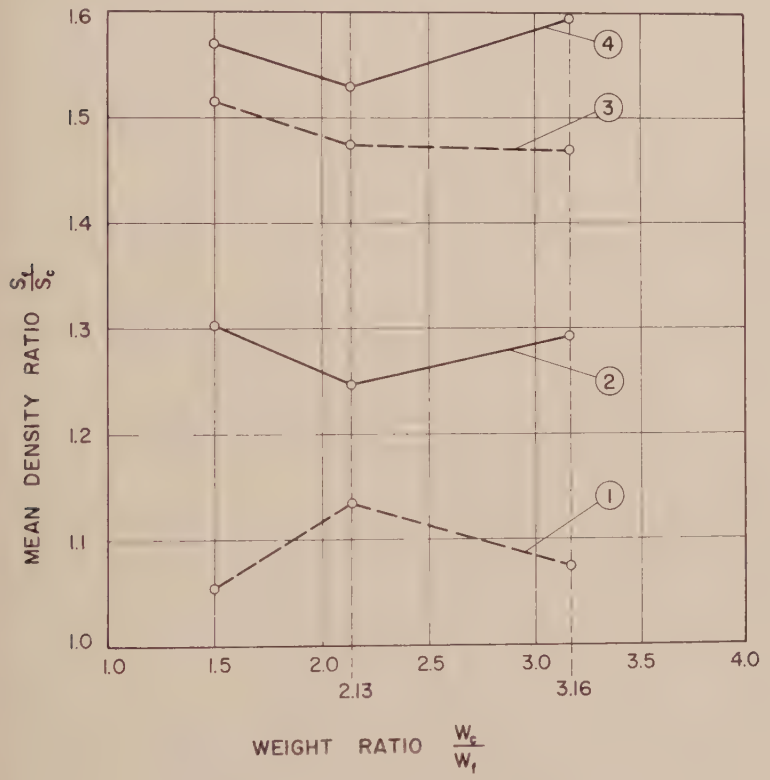
Number	Face moisture content	Closing time
1.	6%	1.5 min.
2.	12%	1.5 min.
3.	6%	0.5 min.
4.	12%	0.5 min.

Fig. 3. Effect of weight ratio $\frac{W_c}{W_f}$ on mean shelling ratio.

all densities on all, both faces were removed from half of all bending specimens for determination of core density. The face densities could then be calculated according to equation (2):

$$S_f = \frac{S_{res} + \lambda S_c - S_c}{\lambda}$$

The results are listed in Table 4. The mean density ratios $\frac{S_f}{S_c}$ are shown in Fig. 4.



Number	Face moisture content	Closing time
1.	6%	1.5 min.
2.	12%	1.5 min.
3.	6%	0.5 min.
4.	12%	0.5 min.

Fig. 4. Effect of weight ratio $\frac{W_f}{W_c}$ on mean density ratio.

TABLE 4—Summary of test results of two-species three-layer flake board (mean values)

Weight ratio $\frac{W_c}{W_f}$	750 g. / 500 g. = 1.50				850 g. / 400 g. = 2.13				950 g. / 300 g. = 3.16				Moisture Content at test—%
Moisture content of face material	6%		12%		6%		12%		6%		12%		
Closing time (min.)	0.5	1.5	0.5	1.5	0.5	1.5	0.5	1.5	0.5	1.5	0.5	1.5	
Overall density S_{res} g/cm³	.708	.685	.705	.682	.707	.686	.715	.689	.719	.676	.701	.670	
Core density S_c g/cm³	.608	.643	.591	.619	.627	.658	.636	.643	.660	.665	.632	.629	
Face density (calc.) S_f g/cm³	.922	.762	.931	.795	.801	.749	.959	.803	.959	.714	.995	.807	
E_c 1,000 psi	843 ±80.1	678 ±52.3	856 ±44.2	759 ±59.1	753 ±66.4	656 ±40.0	810 ±47.5	742 ±48.4	760 ±42.4	599 ±61.2	795 ±82.6	699 ±65.0	6.02
E_c 1,000 psi	302	360	273	315	335	353	312	318	381	362	336	329	6.02
E_f (calc.) 1,000 psi	1,091	793	1,099	921	1,006	838	1,183	978	1,168	803	1,315	959	
MR_{res} psi	6,190	5,140	6,000	4,980	6,050	5,040	5,540	4,840	5,540	4,000	5,400	4,310	6.02
MR_c psi	2,450	3,000	2,070	2,400	2,960	2,980	2,400	2,510	3,150	2,840	2,660	2,620	6.02
Shear strength psi	287	429	302	310	377	505	298	375	412	522	368	430	7.66
Tensile strength psi	74	138	78	92	116	165	81	127	129	137	94	129	7.96

The Modulus of Elasticity in Bending

The modulus of elasticity was determined on standard bending test specimens for the three-layer board as well as for the core alone (Table 4). E_f could then be calculated according to equation (4):

$$E_f = \frac{E_e - E_c (1-\lambda)^3}{1-(1-\lambda)^3}$$

There is a strong correlation between S_c and E_c and between S_f and E_f. The equations for the regression lines are:

(5) $E_c = 1000\, S_c - 303$ and

(6) $E_f = 1618\, S_f - 362$ (see Fig. 5)

By substitution E_e can be expressed in terms of λ and S_c or in terms of λ and S_f for any given overall density S_{res}.

For an overall density of 0.700 g/m³:

$$(7)\quad E_e = (1618 \frac{0.7 - S_c (1-\lambda)}{\lambda} - 362) - (1-\lambda)^3 \left[(1618 \frac{0.7 - S_c (1-\lambda)}{\lambda} - 362) - (1000 S_c - 303)\right]$$

or:

$$(8)\quad E_e = (1618\, S_f - 362) - (1-\lambda)^3 \left[(1618\, S_f - 362) - (1000 \frac{0.7 - S_f \lambda}{1-\lambda} - 303)\right]$$

Equations (7) and (8) represent lines of equal core density or equal face density, respectively, in a graph having E_e as ordinate and λ as abscissa. Such a graph is shown in Fig. 5 for the range indicated by the core and face densities. (Similar graphs could be drawn for other overall densities which could be combined in a three-dimensional figure in which equal core and face densities would be represented by surfaces.)

Any point in Fig. 5 is determined by any two of the four variables.

If the three-layer flake boards would be manufactured by a two-step process, i.e., a separate manufacture of core and face layers with subsequent lamination, core and face densities could be combined at appropriate shelling ratios to correspond to any point on

the graph. The combination for the highest modulus of elasticity obtainable (within the range outlined in Fig. 5) would be for example:

$$S_c = 0.550 \text{ g/cm}^3$$
$$S_f = 1.000 \text{ g/cm}^3$$
$$\lambda = 0.33$$
$$E_e = 960{,}000 \text{ p.s.i.}$$

In the one-step process, i.e., simultaneous manufacture and lamination

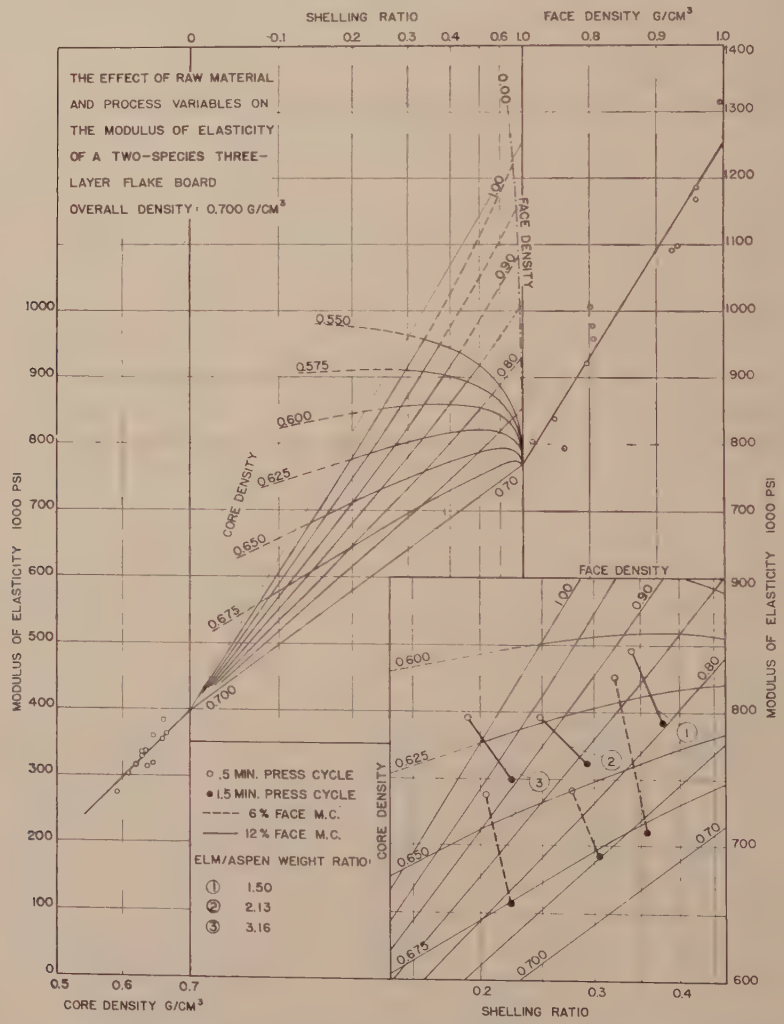


Fig. 5. Effect of raw material and process variables on the modulus of elasticity in bending of a two-species, three-layer flake board, overall density: 0.700 g/cm³.

of core and face layers, all layers are subjected to the same press cycle and the variability of the density ratio $\frac{S_f}{S_c}$ is limited. It can only be varied by providing raw material and press cycle combinations which, on account of the relatively slow heat transfer, will affect the compressibility of the faces to a different degree than that of the core.

It is doubtful that a combination, as given in the above example, can be obtained by the one-step method.

The relationship between raw material and press cycle variables and the final density ratios can be illustrated by including the results of the bending tests in Fig. 5 (see inserted graph). Each point represents the mean of 8 samples. M. E.[4] and shelling ratios were adjusted by the method of the least squares to an overall density of exactly 0.700 g/cm^3. This graph offers several possibilities for improving the board with regard to its modulus of elasticity. Shorter closing times, i.e., higher initial pressures, and higher moisture content differences will increase the M. E. at various shelling ratios, which, in turn, are most significantly affected by the weight ratio. A variation of shelling ratios or weight ratios might be limited by cost considerations, since the higher glue content in the faces increases the raw material cost as the weight ratio is reduced. Also, the procurement of the face flakes might be more expensive (more flakes per unit weight) than that of the core flakes. A further increase of the M. E. might also be undesirable because other properties of the board might be adversely affected by further reducing the core density.

Shear Strength and Internal Bond Strength

The shear strength in the plane of the board and the tensile strength perpendicular to the surface of the board (internal bond) were determined according to standard specifications (see Table 4).

The results of the shear tests represent the shear strength of the core alone. The shear strength of the faces was not determined. Similarly, the results of the tension tests represent the tensile strength of the core alone, since failure occurred in the core in all cases. Both properties are important quality indicators because screw holding power, machineability and other related properties which are more difficult to determine can be estimated on the basis of shear and tensile strength.

[4] M. E. = Modulus of Elasticity.

As shown in Fig. 6, both properties are linear functions of the core density. Lines of equal core density in Fig. 5 are therefore lines of equal shear and tensile strength. Lines of equal shear strength in intervals of 50 p.s.i. are shown in Fig. 7, which again shows the results of the bending tests.

The shear strength and other related properties could be improved within limits by increasing the shelling ratio and maintaining the stiffness, or by increasing the core density and maintaining the shelling ratio. In the first case, the cost of the board would rise and in the second case, the stiffness would be reduced. The ideal combinations, regardless of cost, are located on a line connecting the maximum of the core density curves.

The results of the bending tests can be used for a rough approxi-

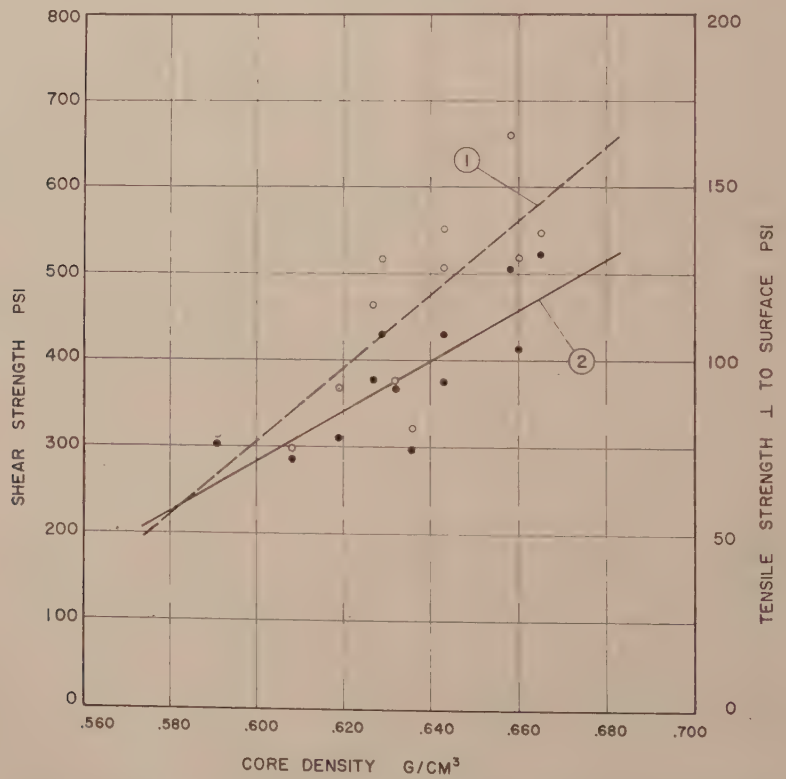


Fig. 6. Shear strength in the plane of the board and tensile strength perpendicular to surface as functions of core density. Equations of regression:

$$1.\ \sigma = 1058.7\ S_c - 558.2$$

$$2.\ \tau = 2919.4\ S_c - 1467.1$$

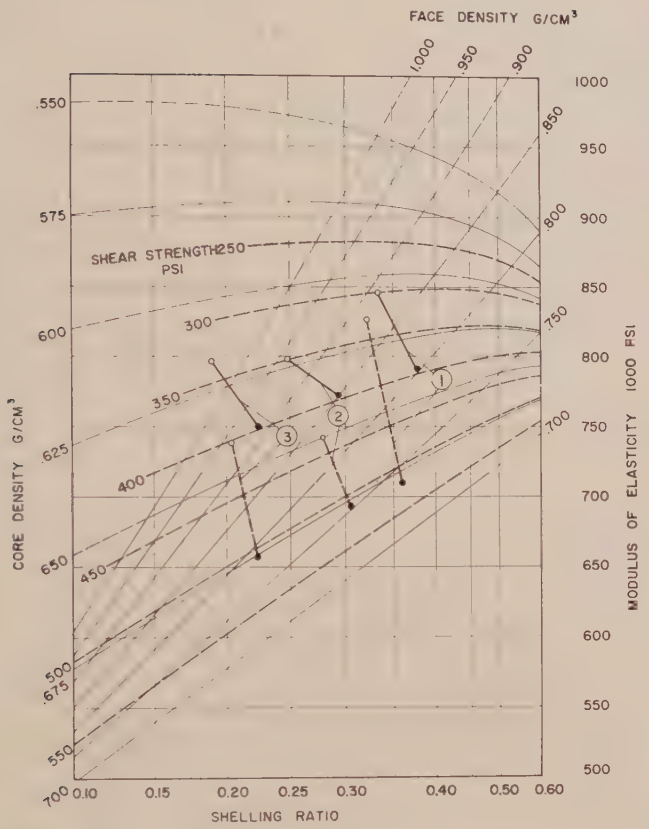


Fig. 7. The effect of raw material and process variables on the modulus of elasticity in bending and on the shear strength of a two-species three-layer flake board, overall density: 0.700 g/cm³ (see Fig. 5).

mation of the combination of raw material and process variables necessary to produce a board having the properties corresponding to any given point on the graph.

The fact that any point in graph 7 is determined by any two of the five variables might simplify production quality control, since any deviation of the process from a given point on the graph might reveal its causes by its direction.

The Effect of Species, Particle Geometry and Resin Content

Although it was not the object of this study to investigate the effect of the three raw material variables: species, particle geometry,

and resin content on the properties of a three layer board, a discussion of these important variables shall be included.

The linear relations between M. E. and core or face densities, respectively, between shear strength and core density, and between tensile strength and core density depend only on the density of the species, flake geometry and glue spread. These relations are the basis for the graphs shown in figures 5 and 7. They will only change when one or more of these three raw material variables is varied. They do not depend on moisture content or press cycle and can be established independently for any combination of species, flake geometry and glue spread.

Equation (5) and (6) representing the M. E. density relation of core and faces could be written in a general form.

(5a) $E_c = A_c S_c + b_c$ and

(6a) $E_f = A_f S_f + b_f$

The results of an earlier study[5] suggest that the constant A, which determines the slope of the linear M. E. density relation, depends on flake geometry alone. It does not depend on the density of the wood nor on the glue spread. Since the relative compression area of a flake mat, which is an indicator of the glue line contact between flakes, is exactly 50 percent if the mat is compressed to a density equal to that of the wood used regardless of flake geometry, the M. E. of boards compressed to that density should also be equal, regardless of flake geometry. Any change in flake geometry would merely rotate the M. E.–density line about a point located over the flake density.[5] The ordinate m of this point is then a function of glue line quality depending on glue spread and the glueability of the species in question under the conditions provided in the hotpress. According to Fig. 8 equation (5a) and (6a) can now be rewritten as follows:

(5b) $E_c = A_c S_c + m_c - A_c S_{wc}$

(6b) $E_f = A_f S_f + m_f - A_f S_{wf}$

where S_{wc} and S_{wf} are the densities of face and core flakes respectively.

A is a function of flake geometry and can be shown to be inversely proportional to the $\frac{\text{flake length}}{\text{flake width}}$ ratio (R) and the flake thickness t;

[5] Ibid, footnote 3.

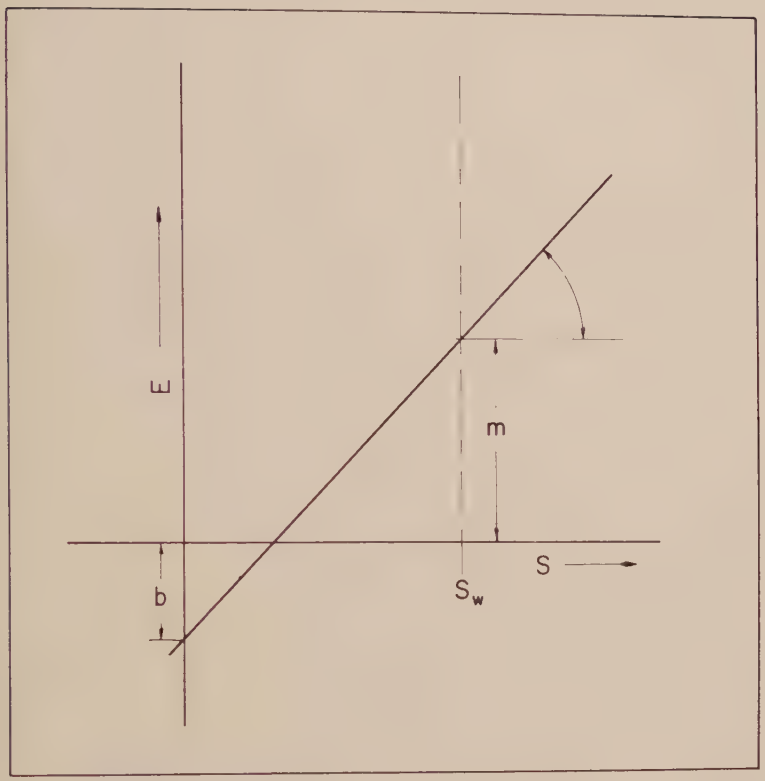


Fig. 8. Modulus of elasticity as a function of board density.

m can be assumed to be a linear function of the glue spread per total flake surface area for a given species up to a point at which the glue line strength exceeds that of the wood.

Obviously, these conclusions are valid only for a limited range of flake sizes.

Although m_f and m_c are about the same in the three-layer board described in this study, the sandwich effect is rather strong due to the difference in compressibility of face and core material (Fig. 9). The solid parts of the two heavy lines indicate the density regions which could be combined in a three-layer board of an overall density of 0.700 g/cm^3.

By reducing R and or t of the Aspen flakes, the slope of the M. E. density line would be increased as well as the compressibility of the faces. This would result in a higher E_f.

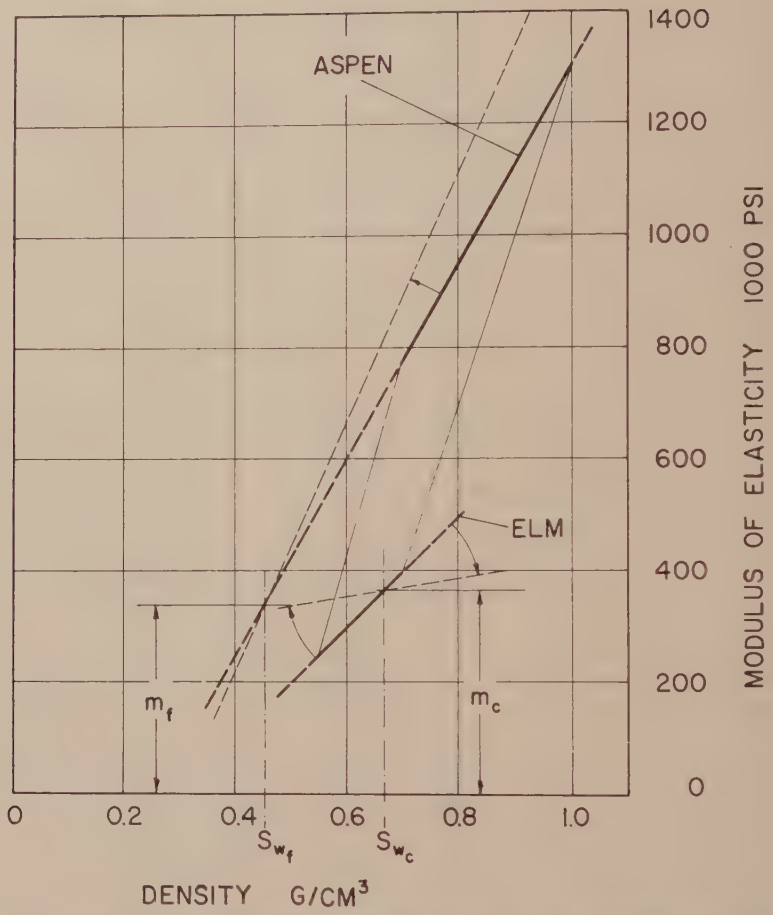


Fig. 9. The effect of flake geometry on the modulus of elasticity-density relation.

Increasing R and or t of the Elm flakes would reduce the slope of the M. E. density line, which would result in a reduction of E_c for $S_c > S_{wc}$ and in an increase of E_c for $S_c < S_{wc}$. The compressibility of the core would be reduced. Shear and tensile strength would be similarly affected.

Summary

A three-layer flake board is a sandwich construction manufactured in a one-step process. The manufacture of the individual layers and their lamination are subject to the same press cycle. This fact limits

the density ratio of core and face and makes a direct control of the board properties impossible.

The relation between core density, face density, shelling ratio and equivalent modulus of elasticity in bending can be expressed mathematically for a given raw material combination. This relation is graphically demonstrated for a two-species, three-layer flake board consisting of aspen faces and elm core at an overall density of 0.700 g/cm^3. By including the test results in this graph, the effects of certain raw material and process variables on the board properties are demonstrated.

RAINFALL PROBABILITIES DURING THE CROP SEASON IN SOUTHERN LOWER MICHIGAN

By A. H. EICHMEIER[1] and W. D. BATEN[2]

WHAT ARE THE CHANCES of having rain within one, two or three days after a given date during haymaking, corn planting, or harvesting? In an effort to produce some useful facts on what occurs, on the average, during these periods in Michigan, 91 years of weather records at East Lansing were summarized and tabulated.

East Lansing records were chosen because of the extra long, continuous and accurate records available. Beginning in 1864 a cooperate weather station was established on the Michigan State University campus with the University and the Weather Bureau as the cooperators. Professor R. C. Kedzie, head of the Chemistry Department, took the observations for a long period of time and did some excellent work for the Weather Bureau, making accurate and consistent readings. In 1910, the Weather Bureau established an office on the campus and took over the observation work. Records for some of the early years, namely 1867, 1875, 1892 and 1893 were missing.

In determining a day with rain, it was decided that any amount of .01 of an inch or more would be considered a day with rain and tabulations were made showing days with and without rain for the entire period of record during the 6 months' growing season, April 1 to September 30, for 91 years. Total days with and without rain were then obtained for each date during the 6 months' period and chances of rain in the next one, two, or three days, expressed in percentages, were then computed.

Considerable day to day variation was observed along with a seasonal trend. To determine whether or not the daily variations were real or due to sample size the following steps were taken. First

[1] State climatologist for Michigan, U. S. Weather Bureau, East Lansing, Mich.

[2] Michigan Agricultural Experiment Station statistician and professor of statistics, Mich. State Univ., East Lansing, Mich.

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a cubic parabola was obtained by the least squares method. Then the seasonal trend, as shown by this curve, was removed by applying corrections as indicated by the difference in the curve and the seasonal mean, and then applying Chi Square tests to the resultant data.

These tests showed that the daily deviations did not exceed Chi Square significant values in more than 5 percent of the cases, indictating a high probability that all values were drawn from the same population.

Therefore, daily mean values were obtained from data extracted from the curves, and these values, showing probability of having rain in one, two or three days after a given date are given in Tables 1, 2, and 3. For instance, for the date of May 10, the probabilities

TABLE 1—Probability of it raining .01 inch or more the next day after a certain date (%)

Date	April	May	June	July	August	September
1	31.3	31.3	29.3	26.7	24.7	24.7
2	31.3	31.3	29.2	26.6	24.6	24.8
3	31.3	31.3	29.1	26.5	24.6	24.8
4	31.4	31.2	29.1	26.4	24.6	24.9
5	31.4	31.2	29.0	26.4	24.5	25.0
6	31.5	31.1	28.9	26.3	24.5	25.0
7	31.5	31.1	28.8	26.2	24.5	25.1
8	31.5	31.0	28.7	26.1	24.4	25.2
9	31.5	31.0	28.6	26.1	24.4	25.3
10	31.6	30.9	28.5	26.1	24.4	25.4
11	31.6	30.8	28.5	25.9	24.4	25.4
12	31.6	30.8	28.4	25.8	24.4	25.5
13	31.6	30.7	28.3	25.8	24.4	25.6
14	31.6	30.7	28.2	25.7	24.4	25.7
15	31.6	30.6	28.1	25.6	24.3	25.8
16	31.6	30.5	28.0	25.5	24.3	26.0
17	31.6	30.5	27.9	25.5	24.3	26.1
18	31.6	30.3	27.8	25.4	24.3	26.2
19	31.6	30.3	27.8	25.4	24.4	26.3
20	31.6	30.3	27.7	25.3	24.4	26.4
21	31.6	30.2	27.6	25.2	24.4	26.6
22	31.6	30.1	27.5	25.1	24.4	26.7
23	31.6	30.0	27.4	25.1	24.4	26.9
24	31.5	30.0	27.3	25.0	24.4	27.0
25	31.5	29.9	27.2	25.0	24.5	27.2
26	31.5	29.8	27.1	24.9	24.5	27.3
27	31.5	29.7	27.0	24.9	24.5	27.5
28	31.4	29.7	27.0	24.8	24.6	27.6
29	31.4	29.6	26.9	24.8	24.6	27.8
30	31.4	29.5	26.8	24.7	24.6	27.0
31	....	29.4	....	24.7	24.7	....

of having rain within the next 1, 2 or 3 days are 31 percent, 54 percent, and 67 percent, respectively. On August 10 these same probabilities are 24 percent, 44 percent, and 58 percent, respectively. Since there are no great climatic differences between East Lansing and other southern Michigan areas, these figures should be quite accurate, not only for East Lansing, but for other points in southern Lower Michigan, and give farmers, horticulturists and others, a fair idea as to just what are the chances of having rain of .01 inch or more during the succeeding one, two or three days.

These figures can be used in long range planning of agricultural operations. For day to day operations during the season, the daily Weather Forecast would, of course, give a much better prediction of what is going to occur during the next few days.

TABLE 2—Probability of it raining .01 inch or more at least 1 of 2 days after a certain date (%)

Date	April	May	June	July	August	September
1	52.0	54.2	51.7	47.4	44.0	44.6
2	52.3	54.1	51.6	47.3	43.9	44.7
3	52.4	54.1	51.4	47.1	43.9	44.8
4	52.5	54.1	51.3	47.0	43.8	44.9
5	52.7	54.1	51.2	47.0	43.8	45.0
6	52.8	54.0	51.1	47.0	43.8	45.2
7	53.0	54.0	51.0	47.0	43.7	45.4
8	53.1	53.9	50.7	46.5	43.7	45.5
9	53.3	53.9	50.6	46.3	43.7	45.7
10	53.4	53.8	50.5	46.2	43.7	45.9
11	53.5	53.8	50.3	46.1	43.6	46.0
12	53.6	53.8	50.2	46.0	43.6	46.2
13	53.7	53.7	50.1	45.9	43.6	46.5
14	53.7	53.6	50.0	45.7	43.6	46.7
15	53.8	53.5	49.7	45.6	43.6	46.9
16	53.9	53.4	49.6	45.5	43.6	47.1
17	53.9	53.4	49.5	45.4	43.6	47.3
18	54.0	53.3	49.3	45.2	43.8	47.5
19	54.0	53.1	49.2	45.1	43.7	47.8
20	54.1	53.0	49.1	45.0	43.7	48.1
21	54.1	52.9	48.9	44.9	43.7	48.3
22	54.1	52.8	48.8	44.8	43.8	48.5
23	54.2	52.7	48.6	44.8	43.8	48.9
24	54.2	52.6	48.4	44.7	43.9	49.2
25	54.2	52.5	48.3	44.6	43.9	49.5
26	54.2	52.4	48.2	44.5	44.0	49.7
27	54.2	52.3	48.0	44.4	44.0	50.2
28	54.2	52.2	47.9	44.4	44.1	50.4
29	54.2	52.1	47.8	44.3	44.3	50.8
30	54.2	51.9	47.5	44.1	44.4	51.2
31	....	51.8	....	44.1	44.5	....

TABLE 3—Probability of it raining .01 inch or more at least 1 of 3 days after a certain date (%)

Date	April	May	June	July	August	September
1	65.3	67.4	65.3	61.6	58.3	58.3
2	65.5	67.3	65.2	61.4	58.3	58.4
3	65.6	67.3	65.1	61.3	58.2	58.5
4	65.9	67.3	65.0	61.2	58.2	58.6
5	65.9	67.3	64.9	61.1	58.1	58.7
6	66.0	67.3	64.8	60.9	58.1	58.9
7	66.1	67.2	64.7	60.8	58.0	59.0
8	66.2	67.2	64.5	60.7	58.0	59.1
9	66.3	67.2	64.3	60.6	58.0	59.2
10	66.4	67.1	64.2	60.5	57.9	59.3
11	66.5	67.1	64.1	60.3	57.9	59.4
12	66.7	67.0	64.0	60.2	57.9	59.6
13	66.8	67.0	63.9	60.1	57.9	59.7
14	66.9	66.9	63.8	60.0	57.8	59.8
15	67.0	66.9	63.7	59.8	57.8	60.1
16	67.0	66.8	63.5	59.7	57.8	60.3
17	67.1	66.7	63.4	59.6	57.8	60.4
18	67.1	66.7	63.2	59.5	57.8	60.6
19	67.2	66.5	63.1	59.4	57.8	60.8
20	67.2	66.4	63.0	59.4	57.8	61.1
21	67.2	66.4	62.8	59.3	57.8	61.3
22	67.3	66.3	62.7	59.2	57.9	61.5
23	67.3	66.2	62.6	59.1	57.9	61.7
24	67.3	66.1	62.5	59.0	57.9	71.9
25	67.3	66.0	62.4	58.9	58.0	62.2
26	67.4	66.0	62.2	58.7	58.0	62.4
27	67.4	65.9	62.0	58.7	58.0	62.7
28	67.4	65.8	61.9	58.6	58.1	62.9
29	67.4	65.7	61.8	58.5	58.1	63.3
30	67.4	65.6	61.7	58.5	58.2	63.5
31	....	65.4	....	58.4	58.3	....

ULTRA HIGH TEMPERATURE PROCESSING OF DAIRY PRODUCTS

I. Some Characteristics of High-Heat Nonfat Dry Milk[1]

By T. I. HEDRICK

Department of Food Science

THE DEVELOPMENT OF ULTRA HIGH TEMPERATURE (UHT) equipment for commercially processing milk and milk products has created much interest and has raised many questions in the manufacture of high-heat nonfat dry milk regarding moisture absorption, baking quality and effect on the grading factors.

Numerous reports have been published by investigators at the University of Minnesota, University of Wisconsin and University of California on properties of nonfat dry milk from skimmilk subjected to various heat treatments at atmospheric pressure. Also, Harland *et al.* (1) reported on one lot of skimmilk heated with laboratory equipment in a range of 170° to 300° F. for various periods. They reported that heatings, sufficient to denature 80 to 85 percent of the serum proteins, assured adequate loaf volume.

The purpose of this project was to study the effects of ultra high temperature preheating of skimmilk on some of the common characteristics of the resulting nonfat dry milk with emphasis on equipment of the continuous type, and methods that are practical for the average dry milk plant.

PROCEDURE

Skimmilk of good quality was heated to 170° F. with a tubular heater and then pumped through a Rogers' steam injection heater in which the temperature was increased to 220°, 260°, 280° or 300° F. followed by a 30-second hold. The Rogers' heater contained two

[1] The assistance of Dr. W. G. Bechtel, American Institute of Baking, Dr. J. Dizikes, Grading and Inspection Laboratory, Dairy Division, A.M.S., A. V. Armitage and J. Grindrod is appreciated.

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ports for the introduction concomitantly of steam and compressed air, along with deflectors to reduce localized overheating that occurs in the single-stage injectors of simple design.

In the second series of trials the heat treatment of 220° F. for 30 seconds was replaced by heating the skimmilk in a hot well to 185° F. for 20 minutes with continuous inlet and outlet after the accumulation of an adequate volume in the hot well. Upon completion of the holding period the milk flowed into the evaporator.

The skimmilk was condensed to approximately 40 percent solids in a single-stage evaporator which operated at about 110° F. The concentrate was pumped into a second tubular heater and heated to 170° F. It was spray dried in a gas-fired drier having continuous product removal facilities connected to the sifter. The outlet air temperature setting was regulated to obtain approximately 3.0 - 3.5 percent moisture in the nonfat dry milk. After sifting the nonfat dry milk through a 24-mesh screen, representative samples were obtained and the lots were sold for commercial purposes.

The solubility index, flavor and scorched particle testing procedures were those published by the U. S. Department of Agriculture (5). Color of the nonfat dry milk was scored "good", "fair" or "poor" by visual means with a standardized background and source of light. Samples for keeping quality were held 1 year at 75° to 85° F., and scored for flavor by the U. S. Department of Agriculture method. The procedure for curd tension is described in the Milk Industry Foundation Laboratory Manual (4). The undenatured whey protein method was a modification of the Harland and Ashworth method (3). The results were expressed as milligrams of whey protein nitrogen per gram of total milk solids. U. S. Department of Agriculture limits high-heat nonfat dry milk to not more than 1.5 mg. and low-heat nonfat dry milk to not less than 6.0 mg. Medium-heat nonfat dry milk is between these two limits.

The moisture absorption capacity of the nonfat dry milk was determined by the Farinograph procedure of Hoffman, *et al.* (2). Development time was also described by the authors. The white bread baking qualities of nonfat dry milk were tested by the method of the American Institute of Baking. Six percent nonfat dry milk (based on the flour) was used in the formula. Three doughs were prepared: one was under mixed (2 minutes); the second was mixed at the regular time (4 minutes); and the third was over mixed (6 minutes); otherwise, the procedures were the same.

The bread was scored according to the Bread Score Report of the American Institute of Baking. The factors and maximum scores were as follows: volume 10, color of crust 8, symmetry 3, evenness of bake 3, character of crust 3, break and shred 3, grain 10, color of crumb 10, aroma 10, taste 10, chewability 10 and texture 15. Excellent bread scored 90 to 92, very good 87 to 89, good (average) 84 to 86, fair (saleable) 80 to 83 and poor (not saleable) below 80.

In order to observe the influence of season, trials 1 through 13 were conducted during a period of 1 year. The five additional trials (14 through 18) were made during the period of August through April.

RESULTS AND DISCUSSION

The average solubility index results (Table 1) of the nonfat dry milk samples with five preheat treatments (220°, 260°, 280°, 300° F. for 30 seconds and 185° F. for 20 minutes) were within the maximum U. S. Department of Agriculture's extra grade limits of 1.25 ml. In fact all samples (total of 72) were 0.6 ml. or less and only three were above 0.3 ml. The average difference among the samples from the five preheat treatments was not enough to be of practical importance.

The color of the nonfat dry milk was rated good in all trials. No difference was visible among the samples from the five preheat treatments. The scorched particle contents varied among the samples. A correlation between heat treatment and scorched particle content did not exist. Conditions other than preheating temperature of the skimmilk such as temperature and time of exposure in the drier were undoubtedly important in causing the scorched particles. The titratable acidities among the 18 trials ranged between 0.11 and 0.16 percent. None of the samples showed an important difference in acidity due to preheating treatments.

The flavor of the reconstituted nonfat dry milk before storage was rated "good" for the 72 samples (Table 1). No minor consistent trend from the five preheat treatments was observed in the samples. After a 1-year storage the samples preheated to 300° F. for 30 seconds had the largest number of storage off flavors. Four were rated "poor"; seven were rated "fair"; and seven were rated "good". Seven out of 18 decreased to "fair" among the storage samples from the group preheated to 280° F. Less storage flavor developed in the 13 samples heated to 220° and in the 18 heated to 260° F. The five samples heated to 185° F. for 20 minutes rated "good" at the end of the storage.

TABLE 1—The effect of preheating temperatures of skimmilk on characteristics of nonfat dry milk

Number of trials	Heat treatment (degrees F.)	Solubility index (ml.)	Curd tension (gm.)	Whey protein nitrogen (mg./gm.)	Flavor fresh (number)	Flavor 1 year storage (number)
5	185°—20 min.	0.16(*a*)	0.0(*a*)	0.6(*a*)	5 good	5 good
13	220°—30 sec.	.13	13.8	3.6	13 good	4 fair 9 good
18	260°—30 sec.	.18	6.3	2.8	18 good	4 fair 14 good
18	280°—30 sec.	.17	3.0	2.5	18 good	7 fair 11 good
18	300°—30 sec.	.21	0.3	2.1	18 good	4 poor 7 fair 7 good

*Average.

The curd tension (Table 1) was drastically affected by the five preheat treatments. The average curd tension of the trials in the first series was 13.8, 6.3, 3.0 and 0.3 gm., respectively, for 220°, 260°, 280° and 300° F. The five trials having 185° F. preheating for 20 minutes had 0.0 gm. curd tension.

The undenatured whey protein content (Table 1) of the nonfat dry milk samples was influenced by the five heating conditions. Average whey protein nitrogen was 3.6 mg. per gm. of milk solids for the 13 samples preheated to 220° F. for 30 seconds. The averages were 2.8, 2.5 and 2.1 mg. for the 18 samples from nonfat dry milk with a preheating of 260°, 280° and 300° F. for 30 seconds. The five samples of nonfat dry milk with the preheat of 185° F. for 20 minutes had an average of 0.6 mg. which suggests this preheating treatment was much more effective in the production of high-heat nonfat dry milk (1.5 mg. or less) on the basis of the whey protein nitrogen test. None of the samples with the preheating of 220° F. for 30 seconds qualified for high-heat category and only one sample qualified from the group with a preheating of 260° for 30 seconds. In general, none of the four ultra high temperatures used in these trials was consistently effective in lowering the whey protein nitrogen to 1.5 mg. or less.

The percentage of moisture absorption and the development time of the samples in 18 trials are shown in Table 2. The results

within a trial were not always consistent among samples of nonfat dry milk with different preheat treatments. In general nonfat dry milk from skimmilk preheated to 220° F. was a little lower in absorption than from skimmilk preheated to 260°, 280° or 300° F. Samples with these three preheatings showed differences in absorptions but most of the differences were within the accuracy of the test. A consistent trend was not apparent. Preheating to 185° F. for 20 minutes caused the resulting dry product to have a higher moisture absorption than the four ultra high temperatures with the 30-second hold.

TABLE 2—The influence of preheating temperature of skimmilk on the moisture absorption and development time of the resulting nonfat dry milk

Trial number	185° F.—20 min.		220° F.—30 sec.		260° F.—30 sec.		280° F.—30 sec.		300° F.—30 sec.	
	Absorp. (percent)	Develop. (minute)	Absorp (percent)	Develop. (minute)	Absorp. (percent)	Develop. (minute)	Absorp. (percent)	Develop. (minute)	Absorp. (percent)	Develop. (minute)
1	....	....	42.2	24.00	52.5	8.38	49.8	9.13	49.0	9.38
2	....	....	50.2	8.50	55.2	5.75	57.2	1.25	53.2	6.38
3	....	....	45.2	19.50	46.5	20.13	40.9	42.75	52.2	6.50
4	....	....	49.6	10.00	57.4	3.33	47.3	20.25	53.4	6.00
5	....	....	40.0	55.00	42.8	32.25	42.4	36.25	46.0	18.75
6	....	....	<40.0	(a)	42.8	47.50	44.8	35.75	43.3	62.68
7	....	....	39.9	(a)	<40.0	(a)	40.0	77.00	46.5	25.00
8	....	....	<40.0	(a)	42.0	62.00	<40.0	(a)	<40.0	(a)
9	....	....	39.7	46.00	40.0	50.00	40.8	40.50	38.2	50.00
10	....	....	45.8	20.00	49.8	9.50	43.8	24.75	45.8	19.50
11	....	....	39.8	40.00	<40.0	53.00	<40.0	48.00	42.8	26.75
12	....	....	45.8	18.00	39.5	50.00	43.8	23.83	46.8	20.75
13	....	....	40.0	40.00	<40.0	(a)	44.8	18.75	42.0	34.00
14	51.2	10.00	....	.....	38.0	(a)	<40.0	(a)	39.4	85.00
15	53.0	9.00	....	.....	49.4	15.00	43.8	30.50	46.8	19.50
16	50.2	14.50	....	.....	52.2	12.50	50.2	14.25	45.8	13.75
17	57.7	9.00	....	.....	51.9	9.75	43.1	25.75	52.5	8.50
18	60.4	4.00	....	.....	50.0	9.25	43.4	29.50	43.0	36.00

(a) Development time not attained.

Rapid development time (ability to absorb water quickly) is a desirable characteristic of nonfat dry milk. Preheating to 185° F. for 20 minutes caused the fastest development time compared to the other four heat treatments. The trials with 220° F. preheating had the highest percentage of samples that were below the lowest reading of a standard development time and trials with 260° F. were next in this respect. The difference among the samples with the remaining two ultra high preheatings was not consistently of a sufficient magnitude to be considered of commercial importance.

Table 3 presents the loaf volume (cubic inches per ounce) when 6 percent nonfat dry milk was used in the dough formula of white

TABLE 3—The loaf volume of white bread with 6 percent nonfat dry milk from skimmilk having various preheat treatments

Number of trials	Preheat treatment of skimmilk	Volume of bread (cu. in. per oz.) when dough is:		
		Under mixed (2 min.)	Normal mixed (4 min.)	Over mixed (6 min.)
10	Control (no NDM used)....	9.3	9.7	9.7
4	185° F. for 20 min.....	9.4	10.1	9.8
6	220° F. for 30 sec.....	9.0	9.6	8.9
10	260° F. for 30 sec.....	9.0	9.6	9.3
10	280° F. for 30 sec.....	9.3	9.7	9.5
10	300° F. for 30 sec.....	9.1	9.8	9.5

bread. A loaf volume of 9.5 to 10.4 cubic inches per ounce of bread is given a value of 10 (the highest). A volume of 8.5 to 9.5 cubic inches scores 9.5 (good) and 7.5 to 8.4 cubic inches scores 9.0 (fair). The average loaf volume was excellent for all the samples of nonfat dry milk used in the dough that was mixed for a normal time. The ranges were 9.3 to 9.8, 9.0 to 10.2, 9.1 to 10.7, 9.1 to 10.4, and 9.7 to 10.7 for samples with preheats of 220°, 260°, 280° and 300° F. for 30 seconds and 185° F. for 20 minutes respectively.

The trials with under mixing resulted in a volume rating of "good" for all the nonfat dry milks. In the over mixed trials, the nonfat dry milk with preheats of 280°, and 300° F. for 30 seconds and 185° F. for 20 minutes scored "excellent" and the remainder scored "good".

Figure 1 illustrates the influence of 6 percent nonfat dry milk in the formula of white bread upon the average total bread score. Bread that scores 87 to 89 is "very good" and a score of 84 to 86 is "good". While the preheat treatment did effect the average bread scores, all samples had an average rating of "very good" for bread from doughs with normal mixing. The bread scores dropped substantially in the under- and over-mixed doughs for the nonfat dry milk with ultra high temperatures of 220°, 260°, 280° and 300° F. The decrease in bread score was slight in the dough with nonfat dry milk from the preheat of 185° F. with a 20-minute hold.

The ranges in bread score among trials with normally mixed doughs having 6 percent nonfat dry milk with preheats of 220°, 260°, 280° and 300° F. for 30 seconds and 185° F. for 20 minutes were, respectively: 85.5 to 89.0, 85.0 to 90.5, 86.0 to 91.5, 86.5 to 91.0 and 87.5 to 90.0.

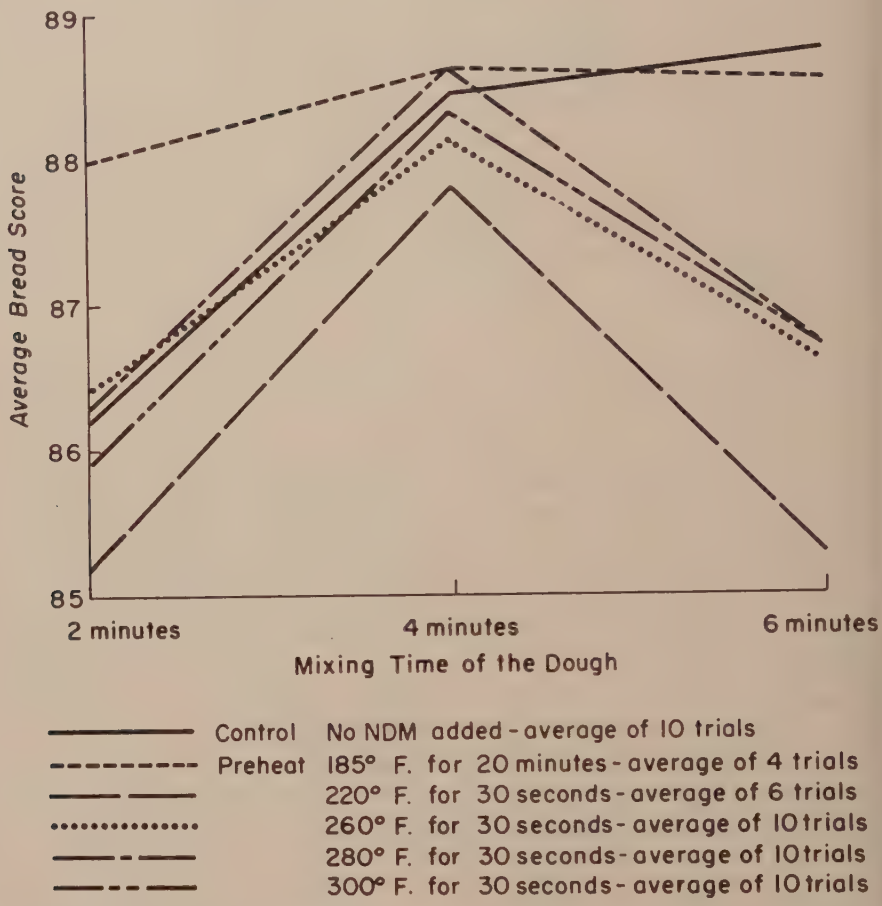
89
88
87
86
85
Average Bread Score
2 minutes
4 minutes
6 minutes
Mixing Time of the Dough
Control No NDM added - average of 10 trials
Preheat 185° F. for 20 minutes - average of 4 trials
220° F. for 30 seconds - average of 6 trials
260° F. for 30 seconds - average of 10 trials
280° F. for 30 seconds - average of 10 trials
300° F. for 30 seconds - average of 10 trials

Fig. 1. Average bread score of doughs with NDM from skimmilk with various preheat treatments.

Of the various factors involved in bread scoring such as symmetry, break and shred, grain, texture, color of crust, volume, aroma, taste, chewability and evenness of bake, loaf volume is particularly critical. Milk solids with insufficient heat treatment has a depressing effect on loaf volume. Furthermore, this milk causes the bread dough to have less tolerance to under or over mixing. The specific constituent in milk which is responsible for the detrimental effect has not been identified.

SUMMARY AND CONCLUSION

Five different preheating treatments of skimmilk during the manufacture of nonfat dry milk in commercial equipment were studied for their effects on the U. S. Department of Agriculture grading factors and on results of utilization tests. Samples from preheats of 220°, 260°, 280° and 300° F. for 30 seconds and 185° F. for 20 minutes did not show an important trend in differences for the solubility index, scorched particles, color or flavor of the fresh nonfat dry milk. A number of samples with 300° and 280° F. preheats had a storage off flavor after 1 year at room temperature. The curd tension was decreased in the following order: 220°, 260°, 280°, 300° (30-second hold) and 185° F. (20-minute hold).

Average whey protein nitrogen per gram of nonfat dry milk was 3.64, 2.70, 2.51, 2.12 and 0.64 mg. for 220°, 260°, 280°, 300° (for 30 seconds) and 185° F. (for 20 minutes), respectively, indicating a medium heat nonfat dry milk from the four highest temperatures and a high-heat product from the 185° F. for 20 minutes.

The Farinograph moisture absorption and development time were best in samples having the preheat of 185° F. for 20 minutes. Differences that were observed among samples from 260°, 280° and 300° F. for 30 seconds were not consistent. This group ranked second for both factors. The least absorption and slowest development time were usually in the samples with the preheat of 220° F. for 30 seconds.

Normal mixed doughs (4 minutes) with 6 percent nonfat dry milk from all five preheat treatments resulted in bread with "very good" or "excellent" loaf volume and "good" or higher total bread score in all trials. The average bread score was "very good" and the average loaf volume was "excellent" for samples with the five different preheats. These doughs varied in their tolerance to over or under mixing. The doughs with the least adverse effect of under or over mixing contained nonfat dry milk from the 185° F. preheating for 20 minutes. The most depressing effect on bread score was exhibited by samples with the 220° F. preheating.

Any of the five preheating treatments can be used in the manufacture of U. S. Extra Grade spray process nonfat dry milk. However the keeping quality, baking quality, curd tension, whey protein nitrogen and moisture absorption of the dry product are affected differently by the preheating treatment of the skimmilk in the ultra high temperature range compared to 185° F. for 20 minutes.

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HEAT PROCESSING CHARACTERISTICS OF FRESH CUCUMBER PICKLE PRODUCTS

I. Heating Rates of Spears

By I. J. PFLUG and R. C. NICHOLAS

DEPARTMENT OF FOOD SCIENCE

FRESH CUCUMBER PICKLE SPEARS are fresh cucumbers that have been sliced, packed in jars or cans, spiced, brined or syruped, sealed and pasteurized. It is an attractive pack of good flavor and texture that is well received by the consumer. The total production of fresh cucumber spear pickles has grown to the extent that it represents a significant percentage of the total pickle pack.

This is the report of a detailed study of the heating characteristics of spear type cucumber pickles.

Spears are produced by slicing the cucumbers lengthwise into four, five or six wedges (Fig. 1); the ends may be cut square (Fig. 2). Spears are hand-packed into containers of such height that the spears, when packed vertically, extend to the top of the jar, but leave adequate head space. The spears are place-packed with the cut surface to the outside. The covering liquor for the dill-flavored pack is a

Fig. 1. Cucumber spears made by slicing the cucumber lengthwise into wedges.

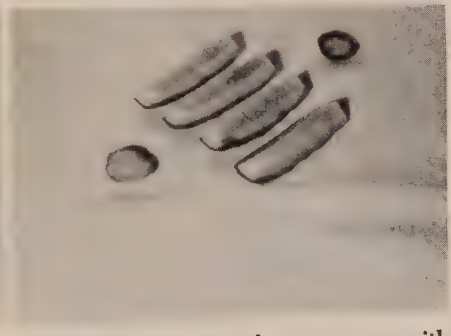

Fig. 2. Cucumber spears with square ends made by slicing end cap before slicing lengthwise.

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salt-acid brine; a sugar-salt-acid syrup is used to make the sweet-spear product. Preservation of fresh spear products is achieved through a heat pasteurization process.

EXPERIMENTAL

The heating characteristics of spears in glass jars and tinplate cans were determined by measuring the temperature at the assumed point of slowest heating with copper-constantan thermocouples sealed in a 1/4-inch O.D. Bakelite rod (similar to the thermocouples described by Townsend *et al.*[1]). The rod was inserted into the container through an Ecklund[2] stuffing box.

In Fig. 3 are illustrated the thermocouple rod unit, stuffing box parts, and a jar of spears with the thermocouple in place. The temperatures were measured and recorded by a multiple-point temperature-recording potentiometer. The heating rate data were plotted according to the method of Ball and Olson[3] and the heating rate, f_h,

[1] Townsend, C. T., J. M. Reed, J. McConnell, M. J. Powers, W. B. Esselen, I. I. Sommers, J. J. Dwyer, and C. O. Ball. (1949) "Comparative heat penetration studies on jars and cans." *Food Technology*, 3:213-226.

[2] Ecklund, O. F. (1949). "Apparatus for the measurement of the rate of heat penetration in canned foods." *Food Technology 3*, 231-233.

[3] Ball, C. O. and F. C. W. Olson. (1957). *"Sterilization in Food Technology."* McGraw-Hill Pub. Co., N. Y.

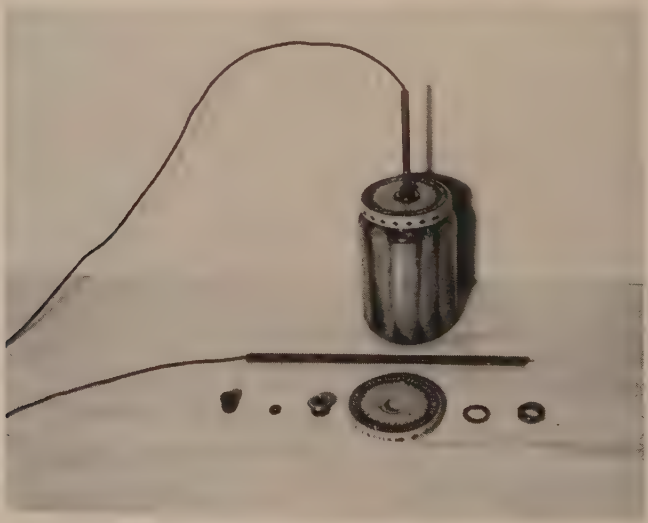

Fig. 3. Apparatus for measuring rate of heating of jars of spears. In the foreground are parts of the Ecklund stuffing box and a lid prepared to receive the stuffing box. The thermocouple is shown in the center of the picture; a jar of spears with thermocouple inserted through stuffing box is shown in the rear of the picture.

and lag factor, j, determined. All tests were replicated and the results of each experiment analyzed statistically. The physical description of the containers used and the location of the thermocouple in inches above the container bottom are given in Table 1.

TABLE 1—Container dimensions

Name	Normal fill (oz.) (*a*)	Outside diameter (in.)	Height to top of finish (in.)	Jar weight (oz.)	Thermocouple distance from bottom of jar (in.)
Vegetable jar (No. 303)..	16	3.00	4.75	7.1	0.90
Tinplate can (No. 2).....	20.5	3.44	4.56	....	0.88
Vegetable jar (No. 2½)..	28	4.00	5.00	12.2	0.90

(*a*) Overflow capacity about ½ oz. more.

Tests were carried out both in the laboratory and in the field. For field tests the laboratory equipment, including the water bath, temperature controller, and temperature recording potentiometer, was moved into the plant of a commercial manufacturer.

Laboratory packs were made using the following procedure: The cucumbers were washed for 5 minutes in a tumbling-action washer, then blanched for 5 minutes at 140° F. The spears were cut by hand and place-packed after cutting. The syrup or brine was preheated to 135-140° F. and poured over the spears; 1 ml. of spice oil mixture[4] was added and the jars were sealed and pasteurized.

The pickles were pasteurized in an automatically controlled water bath maintained at approximately 180° F. for all tests except one when a temperature of 195° F. was used. The point-to-point variation in this bath was determined to be less than 1.25° F., and the standard deviation of the temperature variation at any one point was about 0.25° F.

The laboratory packed jars were filled with a known weight of product. This weight is expressed as a fill ratio, the ratio of the weight of the cucumbers to the nominal fluid ounce capacity of the container; for example, 12-oz. of cucumbers in a 16-oz. jar is described as a fill ratio of 0.75. In the field studies the production-line-packed, LP, product was used for the heating rate studies. The objective in deter-

[4] Courtesy W. J. Stange Co.

mining the heating characteristics of the line-packed products was to compare those data with corresponding data from laboratory packs.

For the laboratory packs a 1.4 percent acid and 5.0 percent salt brine was used to cover the dill spears and a syrup containing 51.0 percent sucrose, 2.8 percent acid, and 4.0 percent salt was used for the sweet pickle spears. The brine or syrup used by the pickle manufacturer was used for the production line packs studied in the field.

RESULTS

The results of tests carried out to determine the effect of the fill ratio on the heating characteristics of spears are presented in Table 2. The 1955 data show a significant difference between the extreme fill ratios, whereas in the 1956 data the difference is not significant; however, there appears to be the same trend toward larger f_h values with lower fill ratios. The lag factors, j, are different in both years. In general, these results show that increasing the fill ratio of a syrup packed product results in a significant decrease in sterilizing value for a given processing time and temperature.

The results of tests comparing skin-in with skin-out are presented in Table 3. In the first test, the cut surface of the cucumber was placed next to the surface of the glass container as is done commercially,

TABLE 2—Effect of fill ratio on the heating characteristics of sweet cucumber spears in 16-oz. jars

Fill ratio	No. jars in test	Lag factor (j)				Heating rate (f_h) min.			
		Ave.	Min.	Max.	Std. dev.	Ave.	Min.	Max.	Std. dev.
1955									
0.69.....	8	1.65	1.18	2.08		38.3	33.1	43.4	
0.75.....	11	1.69	1.43	2.10	0.31	36.0	27.4	41.0	4.78
0.82.....	12	2.00	1.47	2.62		32.0	22.1	45.0	
1956									
0.62.....	9	1.33	1.10	1.51		43.3	36.8	55.2	
0.70.....	12	1.36	1.07	1.72		40.0	34.8	47.6	
0.75.....	6	1.63	1.27	2.04	0.20	41.0	37.2	43.0	4.14
0.84.....	7	1.97	1.48	2.52		38.6	33.2	41.2	

TABLE 3—Effect of cut-surface position on heating characteristics of sweet fresh cucumber spears (fill ratio 0.75; 16-oz. jar; 1957)

	No. jars in test	Fill ratio	Lag factor (j)				Heating rate (f_h) min.			
			Ave.	Min.	Max.	Std. dev.	Ave.	Min.	Max.	Std. dev.
Cut surface next to glass.....	8	0.75	1.64	1.46	1.79	0.12	36.2	33.5	39.3	2.09
Skin surface next to glass.....	8	0.75	1.71	1.59	1.91		40.9	38.2	43.4	

whereas in the second test the skin side of the cucumber wedge was placed next to the glass. The results show that there is a difference, significant at the 1 percent level, in the heating rate. The jars with the cut surface out (skin-in) heated faster than those with the skin out.

Table 4 presents the results of tests to determine the effect of holding filled, syruped, closed containers for 30 minutes before heating. In the first test, the product was syruped and sealed and then allowed to stand for 30 minutes at room temperature before processing. This test was compared with a second test in which the jars were processed immediately after packing. An analysis of variance indicated no significant difference in either the f_h or j value due to the 30-minute hold. There appears to be a trend toward faster heating with increased holding time.

TABLE 4—Effect of time between sealing and heating on heating characteristics of sweet fresh cucumber spears (line pack; 16-oz. jars; 1957)

	No. jars in test	Fill ratio	Lag factor (j)				Heating rate (f_h) min.			
			Ave.	Min.	Max.	Std. dev.	Ave.	Min.	Max.	Std. dev.
Spears held for 30 min. before heating.....	8	LP	1.35	1.15	1.63	0.35	38.5	32.8	45.6	3.85
Spears heated immediately.....	12	LP	1.65	1.25	2.19		39.6	30.8	49.2	

The effect of heating medium temperature on the heating characteristics of line-packed 16-oz. jars of spears in syrup is shown in Table 5. Heating was significantly faster, smaller f_h, in the 195°F bath, than in the 180°F water bath. There was no significant change in the lag factor, j.

Tests were carried out to determine the effect of container type and size and covering liquor on the heating characteristics of the spear products. These data are presented in Table 6. The mean heat-

TABLE 5—Effect of heating medium temperature on the heating characteristics of fresh sweet cucumber spears (line pack, 16-oz. vegetable jars, thermocouple at center of jar)

Water bath temperature °F.	Number jars in test	Lag factor (j)				Heating rate (f_h) min.			
		Ave.	Min.	Max.	Std. dev.	Ave.	Min.	Max.	Std. dev.
180	30	1.58	1.18	2.18	0.44	46.1	35.2	55.1	4.3
195	10	1.28	1.28	1.89		36.2	29.2	41.9	

ing rate, f_h, of 28-oz. syrup packed jars, is greater than the heating rate of 16-oz. syrup packed jars by more than 26 percent. The lag factor, j, also increases. Increasing the jar size from 16 to 28-oz. increased the heating rate of spears in brine by only 17 percent, while the lag factor remained almost constant. If the brine packed product is compared with a syrup packed product in the same size container, the syrup packed product shows an increase in lag factor of about 40 percent and an increase in heating rate of about 100 percent. This effect of the syrup requires that fresh sweet products be given a longer pasteurization process than fresh brine products.

DISCUSSION

A comparison of the heating characteristics of line-packed jars of sweet spears in 1960 (Table 5) with results of other years (Table 6) suggests that some factor in manufacture has changed in 1960 to cause the jars to heat more slowly, larger f_h. The results in Table 2 suggest that this change in heating rate could be due to a decrease in fill ratio. Differences in the location of the thermocouple in the jars, at the geometric center for data in Table 5 compared to 0.90-in. above bottom for other data, should have little or no effect on the heating rate since this product approaches conduction heating. Comparison of the data for a heating medium temperature of 195° F. (Table 5) vs. a heating medium temperature of 180° F. should bring realization that the heating rate is not constant but is influenced by external conditions. It is anticipated that the heating rate will vary with the nature of the heating medium in addition to the variation due to heating medium temperature.

The results of these studies on the heating rate of cucumber spear products are summarized in Table 7. The average values obtained from the data have been statistically projected by adding 3.09

TABLE 6—Effect of container and covering liquid on the heating characteristics of fresh cucumber spears

	No. jars in test	Year	Fill ratio	Lag factor (j)				Heating rate (f_h) min.			
				Ave.	Min.	Max.	Std. dev.	Ave.	Min.	Max.	Std. dev.
16-oz. jars; syrup pack	12	1956	0.75	1.52	1.27	2.05	0.21	40.8	21.3	46.0	6.48
	8	1957	0.75	1.64	1.46	1.79	0.12	36.2	33.5	39.3	2.09
	8	1958	0.72	1.84	1.52	2.26	0.23	40.7	34.5	46.0	3.40
	12	1957	LP	1.65	1.25	2.19	0.34	39.6	30.8	49.2	3.85
	40	1958	LP	1.52	1.25	2.09	0.18	41.9	36.2	48.4	3.74
No. 2 can, syrup pack	6	1957	0.65	1.61	1.40	1.93	0.19	41.3	35.2	48.8	4.37
28-oz. jar, syrup pack	12	1956	0.72	1.67	1.34	1.97	0.20	51.6	40.8	63.3	7.32
16-oz. jar, brine pack	21	1956	0.75	1.21	1.06	1.48	0.11	21.0	17.7	25.6	1.89
28-oz. jar, brine pack	12	1956	0.72	1.17	1.02	1.35	0.08	24.7	23.0	27.2	1.33
	6	1956	0.72	1.04	0.97	1.15	0.06	22.0	20.6	23.4	0.88
	19	1958	LP	1.20	1.00	1.75	0.22	24.2	20.4	29.8	2.65
	30	1960	LP	1.13	0.94	1.36	0.12	22.9	17.0	25.8	2.38

TABLE 7—Summary of cucumber spear heating characteristics

Type of pack and container size	Heating rate (f_h) min.		Lag factor (j)	
	Average	1/1000(*a*)	Average	1/1000(*a*)
Syrup—16-oz. jar	40.1	53.3	1.57	2.23
Brine—16-oz. jar	21.0	26.8	1.21	1.55
Syrup—28-oz. jar	51.6	74.2	1.67	2.29
Brine—28-oz. jar	24.0	30.5	1.16	1.68
Syrup—No. 2 can	41.3	54.8	1.61	2.19

(*a*) The heating rate or lag factor is expected to exceed this value in only one jar out of 1,000.

times the corresponding standard deviation to give a heating rate and lag factor of that jar per thousand that will have the largest heating rate, f_h, and that jar that will have the largest lag factor, j. These or similar projected values should be used in designing the pasteurization process.

SUMMARY

Rates of heating, f_h, and lag factor, j, determined under both laboratory and commercial conditions, are presented for spears in brine and syrup in 16-oz. and 28-oz. glass containers and No. 2 metal cans. The data indicate that:

1. Syrup packs heat more slowly than brine packs, more slowly than would be predicted by considering the jar size or covering liquor effects alone.

2. Holding spears for 30 min. after packing and sealing does not significantly change the rate of heating.

3. Packs in which the cut surface faces out heat faster than packs with the skin side facing out.

4. The heating medium temperature affects the heating rate of spears in syrup.

ACKNOWLEDGMENT

The authors wish to express their appreciation for the invaluable assistance of the management and personnel of the Croswell Pickle Company, Croswell, Michigan.

THE MONTHLY COMPOSITION OF RETAIL FLORIST SALES BY RETAIL MERCHANDISE CLASS

By L. J. TOLLE and EARL H. NEW

INTRODUCTION

THE SEASONAL VARIATION of retail florist sales by retail merchandise class has been previously reported by the authors.[1] In that report the concept of the retail florist "commodity" or merchandise class, was advanced in which the assembled item (arrangement, corsage, etc.) was said to be the significant item for study in retail florist sales analyses. It was further argued that the raw materials (roses, carnations, etc.) have undergone what is essentially a change in *form utility* when they are "made up" into the items sold by retail florists. Each of these classes of retail merchandise experiences its own sales pattern, knows its own demand complex, and may be merchandised as a separate product with distinctive characteristics. The retail items sold from the flower shop were classified into 8 merchandise classes and defined as follows:

1. *Arrangements* —floral pieces made of fresh flowers assembled into containers which contain water.
2. *Floral Designs* —floral pieces made of fresh flowers assembled onto forms or other devices which normally do not contain water.
3. *Corsages* —floral pieces made of fresh materials designed for personal wear.
4. *Cut Flowers* —fresh flowers sold in a wrapped or boxed bunch.
5. *Flowering Plants*—potted, growing plants sold primarily for their colorful flowers.

[1]Tolle, L. J., Jr. and Earl H. New. August, 1959. Seasonal variation in sales of retail florist merchandise. Mich. Agr. Expt. Sta. Quart. Bul. 42(1): pp. 114-125.

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6. *Foliage Plants* —potted, growing plants sold primarily for their ornamental foliage.
7. *Weddings* —all merchandise, *including* any of the other categories above, sold for marriage ceremonies and celebrations as a part of the wedding "package."
8. *Miscellaneous* —all artificial materials, dried materials, giftware, rentals and other items not included above.

The cited report gave an account of the seasonal variation of the five major classes of retail florist merchandise, for example, arrangements, corsages, cut flowers, flowering plants and foliage plants. The variation was expressed in terms of variations of monthly sales of each class from the average monthly sales of the class.

In presenting the data, the *annual average number of orders* for each commodity was equated to 100 and the actual monthly variation was indexed on the average.

Equally significant and important is the *proportion* of sales each merchandise class represents of total sales for each month of the year. This paper presents this information for the six flower stores in Michigan studied for the year 1956.

PROCEDURE AND RESULTS

All sales recorded on sales tickets of six flower shops in four cities of Michigan were recorded for date of delivery, item sold, price and occasion for which the purchase was made (when known). Monthly totals were computed for number of orders and dollar volume for each retail merchandise class.

Number of orders has been used to study variations in sales to avoid differences in prices between shops, variations in content of the assemblies, etc. which would distort the proportions of merchandise classes sold in each month. The number of orders of each class and total monthly orders are shown in Table 1.

Using the number of all orders of each month as the bases for calculation of percentage figures (total number of orders in a month= 100 percent) the percentage that each merchandise class is of all orders was calculated. See Table 2.

TABLE 1—Monthly breakdown of sales in number of orders, by merchandise class, for all of six selected flower stores of Michigan, 1956

Merchandise class	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Arrangements	1,419	1,229	1,222	913	1,316	1,162	1,000	1,342	1,145	1,252	1,163	1,333	14,496
Floral designs	143	106	119	154	213	131	66	110	91	112	83	141	1,469
Corsages	246	314	1,441	566	1,793	464	81	339	163	271	243	725	6,646
Cut flowers	261	527	493	386	638	220	220	217	222	310	234	334	4,062
Flowering plants	364	728	2,641	810	1,638	379	183	195	249	394	440	1,822	9,843
Foliage plants	182	308	359	178	389	177	194	243	208	301	242	357	3,138
Weddings	19	27	23	18	23	43	17	37	33	31	21	29	321
Others	59	141	432	243	455	444	79	117	134	179	168	865	3,316
Totals	2,693	3,380	6,730	3,268	6,465	3,020	1,840	2,600	2,245	2,850	2,594	5,606	43,291

TABLE 2—Monthly breakdown of sales in percent, by merchandise class, of all of six selected flower stores of Michigan, 1956

Merchandise class	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	All 12 Mos.: 1956
Arrangements	52.7	36.4	18.2	27.9	20.4	38.5	54.3	51.6	51.0	43.9	44.8	23.8	33.5
Floral designs	5.3	3.1	1.8	4.7	3.3	4.3	3.6	4.2	4.1	3.9	3.2	2.5	3.4
Corsages	9.1	9.3	21.4	17.3	27.7	15.4	4.4	13.0	7.3	9.5	9.4	12.9	15.4
Cut flowers	9.7	15.6	7.3	11.8	9.9	7.3	12.0	8.3	9.9	10.9	9.0	6.0	9.4
Flowering plants	13.5	21.5	39.2	24.8	25.3	12.5	9.9	7.5	11.1	13.8	17.0	32.5	22.7
Foliage plants	6.8	9.1	5.3	5.4	6.0	5.9	10.5	9.3	9.3	10.6	9.3	6.4	7.2
Weddings	.7	.8	.3	.6	.4	1.4	.9	1.4	1.5	1.1	.8	.5	.7
Others	2.2	4.2	6.4	7.4	7.0	14.7	4.3	4.5	6.0	6.3	6.5	15.4	7.7
Totals	100.0	100.0	99.9	99.9	100.0	100.0	99.9	99.8	100.2	100.0	100.0	100.0	100.0

With the total sales of each month = 100 percent, Table 2 illustrates the relative importance of each merchandise class in the sales of each month.

CONCLUSIONS AND DISCUSSION

The relative importance of eight defined merchandise classes of retail florist sales has been shown. The seasonal variation of total sales, presented by the authors in their previous paper cited, has thus been explained in terms of the *type of merchandise* sold in each month.

The composition of the monthly volume of orders is a useful basis for retail florist production planning. It is known, for example, that the corsage class of merchandise, is a high-cost-per-dollar-income group. Months in which this class represents a large proportion of sales may be (from Table 2) March, April, May, June, August, October, and December. These are times when a retail florist must plan for the specialized labor and supplies to produce this type of merchandise. Further, he will be prepared financially for a busy period from which his income per labor dollar may be relatively low.

Offsetting this influence, however, is the contribution made to the monthly sales picture by a class of merchandise such as Flowering Plants. Here a relatively high income-per-cost-dollar class of merchandise may be resorted to in such months as February, March, April, May, October, November, and December.

The shifts in the relative number of orders in each class, shown in Table 2, tell us as much about retail florist production management strategy as about consumer demand. The retail florist no doubt has a large measure of control over what he sells for any given order. This is especially true of telephone sales. Table 2 reflects his attempt to shift sales to classes of merchandise which require less time and labor to assemble when the design capacity of his workroom is strained.

The *Arrangements Class,* including funeral flowers in this geographic area, represents the largest number of orders in all months but March, May, and December. These months, in which Easter, Mother's Day, and Christmas occur, reflect the influence of holidays on the type of merchandise produced and sold from flower stores.

The data presented in this paper may be applied by the florist business-man who wishes to estimate labor skills and labor times required at various seasons of the year. The data is basic to merchandise

planning and promotional efforts by florists. The budgeting of income and expenditures of florist businesses may be improved with information on the proportional sales relationship of merchandise classes. The florist whose sales pattern differs from those of the sample will seek logical reasons for the differences, bearing in mind the limitations of the material presented here. Throughout the marketing channels for floricultural goods, the performance and variations of retail florist sales have their repercussions. Producers and wholesalers may more closely plan stocks and shipments to retail florist needs as such information becomes confirmed by future studies. The more complete the picture of retail florist sales and operations, the greater degree of control may be exercised over them.

THE AGES AND FUTURE PLANS OF MICHIGAN FARMERS AS RELATED TO AGRICULTURAL ADJUSTMENT

By J. R. BRAKE, D. E. McKEE, and J. T. BONNEN[1]

THIS ARTICLE IS INTENDED to relate the ages and future plans of farm operators in certain areas of Southern and Central Michigan to such characteristics of their farm operation as size of farm, operator tenure, off-farm work status, and operator replacement possibility. These relationships are explored for the purpose of obtaining for future study descriptive information and behavioral hypotheses concerning the current adjustment process on Michigan farms.

Very little is known concerning answers to a number of questions that are central to any comprehensive understanding of the process of economic adjustment and the realistic constraints within which major adjustments of the rural economy must occur. Some of these questions concern the age of the operator and the stage in the family life cycle of himself and his family. The need and desire for, as well as the ability to obtain credit and other resources are conditioned by age and thus by life expectancy.

Many questions arise: Are older farmers concentrated geographically? Are older farmers concentrated on certain types of farms? Thus, are some types of adjustment problems concentrated? Do older or younger farmers tend to operate the larger full-time commercial farms? To the extent that older farmers are relatively important in the production of farm output, they represent important opportunities for and problems in production adjustments as farm assets must be transferred from one generation to the next. Are part-time farmers typically the younger or older farmers? What are the objectives of part-time operators with respect to leaving agriculture, remaining part-time operators, or moving toward full-time farming

[1]Assistant professor of agricultural economics, agricultural economist, farm economic research division, agricultural research service, U. S. Department of Agriculture, and associate professor of agricultural economics, respectively.

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operations? What are the retirement intentions of farmers in these differing situations and what proportions of them have apparent successors in their immediate families?

These questions, as well as others, arise when serious consideration is given to the adjustment process and its effective constraints. Answers to such questions would provide considerable evidence as to the paths of adjustment that may be ruled out for an area, the pace at which certain types of change are likely to occur, the nature and size of the problem involved in transferring ownership of assets and of the management unit between generations, and the drop-out rate of management units from agriculture.

Present knowledge of the process of adjustment is so inadequate that few, if any, answers given here are likely to be conclusive. Indeed, we are not even sure that the appropriate "questions" have been asked in the way of research hypotheses. It was for the purpose of developing the most appropriate research hypotheses for a study of the process of adjustment that the analysis reported here was carried out.

The Sample and Sample Area

The data are part of a larger study being conducted cooperatively by the Michigan Agricultural Experiment Station and the Farm Economics Research Division, Agricultural Research Service, U. S. Department of Agriculture. The study deals with economic adjustments in the Lake States, with primary emphasis on dairy farm adjustments. The data reported here are limited to Michigan.

Three hundred fifty-seven farm operators whose farms are in economic classes I to V (these are the census farm classes with gross sales of $1,200 or more) were selected at random and interviewed in the spring of 1959 in central and southern Michigan. The area covered by the survey is shown by the map in Fig. 1. Also shown are five subareas set up to distinguish among major differences in the environmental and economic conditions confronting farmers in the area surveyed.

The boundaries of the five subareas follow county lines but fall roughly along the divisions between the major soil areas of the state. Area 1 consists of the metropolitan counties around Detroit. This area exhibits a degree of urban influence that differentiates it from the others. Area 2, the Saginaw-Thumb area, is particularly well adapted to cash crops. South-central Michigan is designated as area

Fig. 1. Production areas in Michigan included in Lake States dairy adjustment study.

3; it differs from the other areas, particularly with respect to diversity of farming and soils. Area 4, the north-central part of the state, has a high incidence of very light, sandy soils. It includes significant coniferous forests and is a fringe area to the major milk markets. The soils are generally less productive than in either area 2 or area 3, with resulting lower land prices.

The western edge of the state lying along Lake Michigan is designated as the fifth area. This area, too, has conditions that set it apart from the other four areas. Area 5 includes the southern part of the

major fruit area of the state, which is influenced climatically by Lake Michigan, and is as close to the Chicago and South Bend milksheds as to those of Detroit. These divisions are an attempt to take into account some of the state's major differences in production and marketing alternatives.

Age Distribution of Farm Operators

Let us look first at an historical comparison for several past years of the age distribution of farm operators in Michigan and in the United States as a whole. (See Table 1.) The average age of Michigan and United States farmers has increased substantially. Between 1930 and 1954, the trend was toward a higher proportion of older farmers and a lower proportion of younger farmers in active management of farms in the United States. In Michigan, the proportion of operators under 35 has remained relatively stable since 1940. A definite downward trend is noticeable in Michigan in the proportion of operators in the 35 to 54 age group, while figures for the United States as a whole show no trend up or down. The proportion of farm operators in Michigan in the age groups over 55, which has been consistently higher than in the United States as a whole, shows an upward trend similar to that for the United States.

TABLE 1—Percentage distribution of farm operators by age group for selected years, United States and Michigan

Age group	1930		1940		1945		1950		1954	
	United States	Michigan	United States	Michigan	United States	Michigan	United States	Michigan	United States	Michigan
	Percent		Percent		Percent		Percent		Percent	
Under 35	23.4	13.0	20.3	14.0	17.2	15.4	18.9	15.1	15.1	14.9
35 to 54	48.0	50.2	45.9	46.0	47.6	46.5	46.5	46.0	48.0	42.5
55 to 64	17.5	21.5	19.6	23.0	20.2	22.4	19.8	22.7	20.3	23.3
65 and over	11.1	15.3	14.2	17.0	15.0	15.7	14.8	16.2	16.6	19.3

Sources: McElveen, J. V., March 1957, "Family farms in a changing economy", U. S. Department of Agriculture, *Agriculture Information Bulletin No. 171*, p. 31; and *1954 Census of Agriculture*, U. S. Bureau of Census, Vol. 1, pt. 6, 1956. Table 5, p. 16.

Probably the main dissimilarities between Michigan and the United States found in Table 1 are due to differences in relative farm vs. off-farm opportunities for young people.

On the whole, since the 1930's, opportunities in nonfarm employment for most young people in the United States have been better

than those in agriculture. Thus, the proportion choosing farming has been decreasing. Similarly, opportunities for off-farm employment in Michigan, which is a rapidly growing and highly industrialized state, could be expected to be somewhat better than those for the United States as a whole. This fact could account for the smaller proportion of young farmers in Michigan relative to the United States during most of the period.[2]

The Michigan sample data collected in 1959 are not directly comparable to the census data used in Table 1, chiefly because of differences in the definition of what constitutes a farm. Census figures include many farms that were excluded from the 1959 Michigan survey. The sample survey data, which are the basis for the rest of the tables in this article, include only those farms with gross sales of $1,200 or more. Specialized truck crop and poultry farms are not included in the survey data.

The age distribution of the 1959 sample of Michigan farm operators is given by area in Table 2. The figures refer to the percentages of farm operators whose ages fall within the column heading. The most common group is the age range of 40 to 45. But because

[2]This is perhaps a questionable explanation in most recent years as the automotive industry has had to make major adjustments to automation, changing consumer tastes, and shifting technologies of national defense.

TABLE 2—Percentage distribution of farm operators by age groups and by area, Michigan, 1959

Age group	Area					Total Percent
	1 Percent	2 Percent	3 Percent	4 Percent	5 Percent	
Under 26	4.5	5.2	4.4	3.3	1.6	3.9
26 to 30	3.0	6.5	8.8	3.3	6.6	5.9
31 to 35	6.0	5.2	11.0	9.8	11.5	8.7
36 to 40	7.5	10.3	13.2	22.9	18.0	14.0
41 to 45	23.8	15.6	14.3	8.2	19.7	16.2
46 to 50	9.0	15.6	11.0	13.1	9.8	11.8
51 to 55	7.5	7.8	11.0	13.1	9.8	9.8
56 to 60	13.4	15.6	7.7	14.8	6.6	11.5
61 to 65	14.8	5.2	5.5	4.9	8.2	7.6
65 and over	10.5	13.0	13.1	6.6	8.2	10.6
Total	100	100	100	100	100	100
Average age	Years 49.7	Years 48.6	Years 46.8	Years 47.1	Years 46.3	Years 47.7

the distributions are skewed toward the higher ages, the average age of operators in all areas falls somewhat above the modal group.

When the classes are combined into three groups (1) age 40 or under, (2) age 41 to 55, and (3) age 56 and over, areas 1 and 2 had a higher proportion of farmers over 55 than areas 3, 4 and 5.[3] Conversely, areas 3, 4, and 5 had a greater proportion of farm operators under 41 than areas 1 and 2.

This difference in age distribution might be explained in various ways. Area 1 is an urban fringe where the young people are probably more aware of off-farm opportunities and, in addition, find it difficult to start farming because of the influence of urban competition on land values. Area 2 contains some of the best farmland in the state. Land values tend to be relatively high, and only limited acreages are available for purchase. Cultural and ethnic patterns of this area are often said to lead in the direction of close family land ownership practices, which would limit the ease with which young folks could start farming as independent operators. In the other three areas, these factors are thought to be less operative, and a higher proportion of young people are operating farms.

Other differences between areas of the State are noticeable in Table 2. Area 3 clearly has a single modal age distribution. Areas 1 and 4, on the other hand, seem to have bimodal age distributions. Except for a hole, so to speak, at the 51 to 55 year age group, the area 2 distribution seems to have a large flat top of equal concentration stretching from 41 to 60 years of age. Adequate explanations for these differences are lacking.

In Table 3, the age distribution of farm operators was compared with the size of farm operated. Small, medium, and large farms were defined to contain respectively, less than 100, 100 to 199, and 200 or more tillable acres. Again, the age classes were combined into younger (under 41), middle-aged (41 to 55), and older (over 55) operators. When the three age groups were compared among the three farm sizes, it was found that the small farms had a significantly greater proportion of older operators and that the larger farms tended to be operated by the younger farmers.[4] The modal groups in Table 3 also indicate this tendency.

Probably, the important aspect of the differences by size of farm centers around the large number of older operators on small farms.

[3]Chi square test for age differentials was significant at the .05 level.
[4]Chi square was significant at the .01 level.

TABLE 3—Age distribution of farm operators, by size of farm, Michigan, 1959(a)

Age group	Numbers of farm operators			Total
	Small	Medium	Large	
0-26	7	5	2	14
26-30	5	10	6	21
31-35	14	11	6	31
36-40	19	21	10	50
41-45	24	28	6	58
46-50	24	16	2	42
51-55	9	19	7	35
56-60	22	15	4	41
61-65	16	6	5	27
65 and over	27	11	0	38
Total	167	142	48	357

(a) Small farms have less than 100, medium farms 100 to 199, and large farms 200 or more tillable acres.

Operators over 55 years of age made up 39 percent of the small operators. In contrast, operators over 55 made up only 19 percent of the group managing large farms. For the most part, the group of older operators on the small farms considered themselves to be full-time owner-operators. The data do not indicate whether the existence of a larger, older age group on small farms is due to inability to retire with a reasonable amount of economic security, to a desire to carry on a moderate farming operation rather than retire, or to some other reason.

The relative ease with which farmers were allowed to come under Social Security in recent years would seem to raise a doubt as to whether a lack of economic security was the prime reason for remaining on small farms at this age. At any rate, the existence of a relatively large number of farmers in the upper age brackets seems to suggest that a sizable group of farmers will not be able or inclined to make major long-run changes in investments and organization of their farms. The tendency for the older operators, to be concentrated on the smaller farms suggests that at least a third, and perhaps as many as half of these small operators are unlikely to make significant adjustments in the direction of larger operations or greater commerciality.

The data also suggest the desirability of looking at the relationship between operator age distribution, income and asset distri-

butions, and equity ratios. Attention is drawn to the fact that the hole in the area 1 and 2 age distribution at the 51 to 55 age group previously mentioned shows up also in Table 3, where it is concentrated in the small farm size group. This suggests the need to look at farm size distributions by area and further reinforces the need for a close look at income distributions. It is conceivable that the hole would disappear if size were measured by income, particularly in area 2, which has some of the most productive land in the state. Land, of course, is only one of the inputs in agricultural production and is used in varying degrees of intensity.

Table 4 presents the operator age distribution by the operator's tenure and off-farm work status. A comparison of the modal group for full-time owner operators with operators having a full time off-farm job shows a 20-year differential from ages 56 to 60 for full time to ages 36 to 40 for part-time owner operators. The Chi square test for age differences between full-time and part-time categories also indicated significant differences at the .05 level. There was no significant difference between owners and tenants with respect to age.

The age differences associated with off-farm work are consistent with statements made by some part-time farmers that off-farm work is a means of obtaining additional capital to put into the farm business. The younger farmers would be the ones who would most need the extra financing in becoming established. Second, in general, the younger men are also the ones with the stamina necessary to handle both a farm and a nonfarm job at the same time.

TABLE 4—Age distribution of farm operators by operator tenure and off-farm work status, Michigan, 1959

Tenure and work status	Age group										Total
	Under 26	26 to 30	31 to 35	36 to 40	41 to 45	46 to 50	51 to 55	56 to 60	61 to 65	65 and over	
No Off-Farm Work(*a*):											
Owner operators	2	7	11	18	20	21	22	28	21	28	178
Tenant operators	0	2	2	1	5	3	2	3	1	2	21
Partnerships	1	1	2	2	3	1	3	4	3	5	25
Full-Time Off-Farm Job(*a*)											
Owner operators	7	8	12	24	23	15	5	3	2	2	101
Tenant operators	2	1	1	1	3	0	1	0	0	0	9
Part-Time Off-Farm Job(*a*)	2	2	3	4	4	2	2	3	0	0	22
											356 (b)

(*a*) Farmers were classified into 3 groups: (1) full-time farmers who had no off-farm jobs during the year, (2) part-time farmers who worked at full time off-farm jobs, and (3) full-time farmers who had part-time off-farm jobs.

(*b*) Total is 356 because 1 farm operator could not be classified into any one of the 6 categories.

Future Plans of Farm Operators

Several questions were asked of the farm operators with respect to their future plans. One question concerned the operator's future occupational plans. The replies were categorized into five groups: (1) no change from the present, (2) retire or leave farming, and (3) become full-time owner-operator, (4) become part-time operator, and (5) other change. The replies were cross-tabulated according to several factors.

Expectational differences were found with respect to two factors, type of farm and off-farm employment. There were no differences by size of farm.

Farms with facilities for grade B milk markets were found to have a greater proportion of operators contemplating changes than other farms.[5] Anticipated changes in these dairy farms both with respect to leaving farming and with respect to all other major changes are proportionately greater than for any other type of farm. Probably, this reflects dissatisfaction with the level of income from this type of operation and may be an indication that grade B dairy farms are in rather poor economic adjustment. Conceivably, however, it might reflect an obsolete farm organization in total.

Important expectational differences were found also between operators who worked off the farm and those who had no off-farm job. Table 5 presents the relationships between plans to change and amount of off-farm work. About 9 percent of the full-time owner operators plan to retire or to leave farming. Most of the rest plan to make no change in their status. A few of the tenant operators and members of partnerships plan to become owner-operators or single proprietors.

The changes planned by farmers with a full time off-farm job tend to be toward full-time farming rather than retirement. Only about 4 percent of all those farmers with a full time off-farm job expressed a conscious intention to quit agriculture or retire. About 18 percent indicated that they planned to become full-time owner-operators in the future. Several commented that they expected the capital earned in the off-farm job to finance, to a large extent, their increasing investment and eventual establishment as full-time farmers. Of course, not all those who plan to make the jump to full-time farming are likely to achieve the adjustment.

Attention is drawn, too, to the large proportion (76 percent)

[5]The Chi Square was significant at the .05 level.

TABLE 5—Planned change in operator status related to present status

Present status	Plans for change in status					
	No change	Retire or quit	Become full-time owner-operator	Become part-time owner-operator	Other	Total
	(no. of operators)					
No off-farm work:						
Owner operators	131	12	..	1	2	146
Tenant operators	15	1	2	..	..	18
Partnerships	19	1	4	..	..	24
Total	165	14	6	1	2	188
Full-time off-farm job:						
Owner operators	60	3	14	..	2	79
Tenant operators	4	..	1	..	..	5
Total	64	3	15	..	2	84
Part-time off-farm job: (But consider themselves full-time farmers)	15	1	2	1	1	20
Grand total	244	18	23	2	5	292(*a*)

(*a*) Total is less than 357 because of nonresponse.

of farmers holding full time off-farm jobs who plan no major change in their status. Many of this large majority indicated in the survey schedule their reasons for not planning a change in status: They felt that the off-farm job provided security and a rather steady income, while the farm provided a means of utilizing extra labor of their own as well as that of their family. A large proportion of this group had been raised on farms; they enjoyed living in the country and having some livestock to look after.

Farmers with a full time off-farm job constitute a third of the sample of farms and thus are an important constituent of the Michigan farm scene. This suggests that this type of operation is important in aggregate adjustment considerations and that it would be desirable to determine the relative importance of this sector's contribution to total farm output. This would be most important for weighting adjustment problems for specific commodities and for problems in which adjustments to obtain a balance of output and consumption are the central focus of the analysis.

Few of the part-time operators intend either to leave active farming or to develop full-time commercial farms. For about a fourth to a fifth of all farmers in the total survey, then, some type of part-time operation represents their final organizational adjustment goal. If, as the authors suspect, farmers holding full-time off-farm jobs contribute significantly to the total farm output of the state, further investigation is necessary to identify and classify different types of operations and to establish the associated off-farm occupational patterns and opportunities, education of operator, previous employment, asset and equity position, and other characteristics that may provide clues to the nature and long-run viability of the different types of part-time production organizations in farming.

Consideration was given to the means by which operators planned to transfer their farms to the next owner and whether apparent successors were available. For purposes of this comparison, an apparent successor was defined to be a male member of the family over 14 years old who was, or intended to be, a farmer. By virtue of the definition, it is expected that a high proportion of young farmers would not have apparent successors. However, by age 56 and over, there should be an apparent successor if someone in the family's next generation is to own and operate the farm.

Table 6 indicates that a rather large proportion of farmers over 55 years of age have no apparent successor. Even of those who

TABLE 6—Plan of operator for farm transfer related to age of operator and apparent successor(a)

Transfer plans	Under 41 years		41 to 55 years		Over 55 years		Total
	Apparent Successor	No Apparent Successor	Apparent Successor	No Apparent Successor	Apparent Successor	No Apparent Successor	
	(no. of operators)						
No plans.....	6	35	7	27	7	14	96
Sale.....	2	34	2	24	2	25	89
Lease.....	..	6	2	6	4	1	19
Transfer to heir.....	2	29	24	39	24	24	142
Other.....	1	1	2	..	..	3	7
Total ..	11	105	37	96	37	67	353 (b)

(a) Apparent successor is defined as a male member of the family 14 years of age or older and who is currently engaged in farming or, in the respondent's opinion, is likely to become a farmer.
(b) Total is less than 357 due to nonresponse.

planned to transfer the farm to an heir, only half had apparent successor-operators within the immediate family. The other half will evidently pass the farm on to a wife, a nonfarming child, or a more distant relative.

A number of factors may contribute to this situation: (1) Often parents are not ready to retire by the time children are ready to start farming; (2) The size of operation predominant in this older group of farmers was too small to permit a son to begin farming on the home farm before the parents retire; (3) In many instances these farms are too small for economical operation, so there is even less incentive for one of the children to plan to take over the farm. The implication, then, is that a large proportion of the farms owned by farmers over 55 will either be absorbed into nearby units in which case the number of Michigan farms will continue to decrease, or they will be operated as part-time farms. Absorption of these units by others could be of help to the adjustment process in Michigan agriculture as many of these small farms (less than 100 tillable acres) become available for addition to existing units to enable them to attain a more economical size.

A final point is the relatively small proportion of older farmers who plan to retire. Of 38 operators who were over 65 years old, only 11 indicated that they planned to retire. The rest planned to continue farming for an indefinite period. Of the 106 who were over 55 years old, only 17 were considering retirement. For the most part, these Michigan farmers evidently desire to continue farming as long as they are able to do so.

Current United States mortality tables indicate that 17 of this group of 106 farmers 55 years old and older can be expected to die within the next 5 years and 37 (35%) within the next 10 years. Of the sample of 357 farmers of all ages, it may be expected that 24 (6.8%) will die within 5 years and 55 (15.4%) within the next 10 years.[6] Farm mortality rates are somewhat higher than United States averages so the above figures may understate slightly the actual mortality rates that may be expected. Obviously, the current provisions for retirement and transfer of farm operations are inadequate. Many of these units will undoubtedly be absorbed into other farms as their operators pass from the scene without direct provision for transfer of the farm's assets to the control of another manager.

[6]Life Insurance Fact Book (1959). Institute of Life Insurance, New York, 1959, p. 110-111.

Conclusions

Older farmers tend to be concentrated on the smaller farms. But as they tend to own the farm and can live on the earnings from their capital as well as their labor, they intend, and probably can continue, to operate the farm in some degree of intensity as long as they are physically able to do so. These farmers are unlikely to be forced out of agriculture via economic pressures. The larger farms tend to be manned by the younger men. Perhaps this is because younger men recognize that a rather large business is necessary to obtain a sufficient income to make a living as well as to service the relatively large debt they must incur in becoming established. Thus, they either get into an operation larger than is currently average, or else go to a nonfarm occupation. It was not possible to give more conclusive reasons for this phenomenon due to insufficient data.

With older farmers concentrated on smaller farms, future problems may arise with respect to the disposal of these farms. Many of these small farms will be added to existing units, as has been the trend in the last few years. But what of the others? Will the prospective owner or heir be in a position to organize an efficient size of unit? Will he be able to obtain the financing that clearly will be necessary to insure an adequate size of business to pay a reasonable return to the operator's management and labor? Will it be necessary, and feasible either for the next owners of these smaller farms to get off-farm jobs to obtain additional capital to expand and enlarge the business or to complement a part-time farm operation?

Also, the objectives with respect to farming operations of the rather large group of operators in the 55 years and over grouping differ considerably from those of farmers in the younger age groups. Security in old age and a desire to continue farming, which to them is a desirable way of life, appear by inference to be the main objectives of this group. These objectives may call for a type of farm plan differing considerably from that of younger families whose needs create a pressure for increasing incomes. At the same time, the objectives of the 55 and older age group will limit the extent and scope of individual farm adjustments, as well as the length of the planning horizon.

Several characteristics of part-time farmers seem to be clear. Part-time farmers are younger than full-time farmers. Less than a fifth of the part-time farmers have aspirations to become full-time owner operators. The off-farm jobs were important sources of capital for

improvement of their farm operations. Most important, however, more than three-fourths of all the part-time farmers planned to remain part-time farmers. Apparently, they appreciate the extra security and steady income from the off-farm job while at the same time they are able to take advantages of the benefits of farm living. The problems and goals of adjustment of this group, a fourth of all farmers, in the survey differ greatly from those of full-time commercial farmers.

Farmers who are now reaching retirement age have been able, for the most part, to attain full-owner-operator status. One may well speculate as to whether this will continue to be true. Those farmers who were able to become full owners did so on farms and at a time that required considerably less investment over their lifetime than is necessary today. The minimum necessary bundle of resources grows larger each year. In addition, a part of the period over which this occurred (during and after World War II) was a relatively profitable period in agriculture. Before a farmer can expect to obtain full ownership of a farm of economical size in the coming years; (1) he may need a good deal of family assistance, (2) he (and possibly his wife also) may need a good off-farm job, or (3) he may need to use profitably a great deal of credit.

These data confirm the complexity of the organization of agriculture and the characteristics of those who provide most of agriculture's management and labor. Some of these results were as might have been expected, but others were unusual or at least contrary to common notions about Michigan's agriculture. Further adjustment research is being pursued. After development of the survey data with respect to some of the questions raised here, one should have the basis for formulating more relevant and clearer hypotheses for research into the adjustment of Michigan's agricultural economy.

DETERMINATION OF VIRUS ENTITIES IN AN APPLE SCION/ROOTSTOCK TEST ORCHARD

Report I

By DONALD CATION and R. F. CARLSON

Departments of Botany and Plant Pathology and Horticulture

INTRODUCTION

Within recent years a number of hitherto unknown apple viruses have been observed. Many of these are latent in standard apple varieties and clonal rootstocks. A virus is considered latent when it is present in a plant without producing symptoms. These latent viruses are demonstrated when transmitted to sensitive varieties and clones. For example, a virus causing stem pitting produces symptoms only on certain sensitive varieties. Stem pitting results when disorganized bark cells grow into the wood showing rough ridges or pits when the bark is peeled away.

The losses from virus infections are not well established; certainly some are minor when viruses are latent, but the stem pitting virus has caused large scale tree stunting and yield reduction in orchards on Virginia Crab rootstock. Such losses may be observed only after years are wasted in developing an orchard.

With the increasing practice of using clonal rootstocks for apple trees, there is a great possibility for extensive spread of latent but potentially harmful viruses. Therefore, it is increasingly important to establish virus-free sources of varieties and clonal rootstocks. Furthermore, the desirability of certain variety/rootstock combinations must be interpreted in relation to possible virus infection.

The present study was begun in 1959 to determine the extent of viruses present in currently growing apple trees, and to procure and preserve disease-free clones for distribution to propagators. The data obtained warrants a preliminary report.

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The observations reported here deal with the indexing of trees in an experimental apple orchard planted specifically for study of interstocks and the hedgerow planting system of culture. This orchard was planted in 1956 at the Horticultural Farm at East Lansing, Michigan. One-year-old trees composed of several varieties of apples, of rootstocks, and of interstems were planted in rows 15 feet apart and spaced 6 feet apart in the row. The apple varieties planted were Jonathan, Red Delicious, Golden Delicious, Winesap, McIntosh, Delcon, Richared, Lodi, Jonadel, Northern Spy and Cortland.

Rootstocks used were seedlings of Columbia, Bedford, Dolgo, Hopa, and rooted clones established through nurse rooting for Red Delicious, Prairie Spy, Sharon, Early Redbird, Victory, Fireside, and Virginia Crab. The interstems used between some of these rootstocks and varieties were Ottawa-524, Robin, Clark, East Malling IX, EM VII, K 41, Muzalma, and Alnarp-2 (A2). The following single budded trees were also planted in this orchard: Rhode Island Greening/EM I, Northern Spy/EM I, Cortland/EM I, McIntosh/EM I, and Red Delicious/EM I. Three trees of each variety/interstem/rootstock combination were planted for a total of 219 trees. Only a few of these trees required replacement.

The trees were propagated by the Interstate Nurseries at Hamburg, Iowa. In any series of three or more trees, it is not known whether the trees were propagated from a single tree of a variety or from several trees of the same variety. Therefore it was not expected that all three trees of a series would show the same virus content.

The overall plan of the experiment is to determine the virus content of these trees by direct examination for stem pitting and by indexing on known indicator varieties for latent viruses. The effect of the viruses on the trees will be evaluated later, from year to year. The work reported here consists of indexing on R12740-7A for chlorotic leaf spot in the greenhouse during the winter of 1959-60 (this variety is an indicator for this reaction). Direct examination was made for stem pitting in June 1960. Chlorotic leaf spot was first described by Mink and Shay (1959).

For indexing, buds of R12740-7A were chip budded to one-year-old domestic apple seedlings after dormancy was broken. When the bud sprouted, the inoculation was made by inserting a bud of the tree to be indexed a few inches below and in line with the R12740-7A sprout. If the virus was present, the chlorotic-leaf-spot symptoms

appeared in about 12 to 20 days. If no symptoms appeared, the indexing was repeated on another indexing tree to verify the original negative reading.

RESULTS

Chlorotic-leaf-spot Determinations

The chlorotic-leaf-spot syndrome first consists of epinasty of the terminal growth, followed shortly by a unilaterally unequal development of the tip leaves. Various degrees of chlorotic leaf spots appear and growth ceases. These symptoms are shown in Fig. 1. A partial listing of the individual trees, their scion interstock/rootstock components and their positive or negative reactions for the chlorotic-leaf-spot syndrome is given in Table I and the list is completed in Tables 2 and 4. Of every clonal variety used in these tests, there were found both reactors and non-reactors. The reactions could have resulted from virus contained in the variety or in the interstock but seedling contamination seems unlikely (Cation, 1960). Of the 215 trees indexed 119 or 56 percent showed positive transmission of the chlorotic-leaf-spot virus entity.

There was no definite pattern of virus content in most of the varieties or interstocks. However, there was a trend showing that rootstocks EM IX, VII, and I were carrying the chlorotic-leaf-spot

Fig. 1. Symptoms on R12740-7A apple resulting from indexing inoculations, left—first indications consisting of tip bending and one-sided leaf development. Right—later indications of arrested growth, with severe mottling.

entity in considerable proportion. This agrees with other concurrent indexings of similar EM rootstocks from several Michigan sources of stooling beds. The Winesap trees on O-524 and Robin interstocks appeared free of the chlorotic-leaf-spot virus (Table I).

TABLE 1—Results of indexing on R12740-7A some scion/rootstock apple combinations for chlorotic-leaf-spot virus content(a)

Tree components	Trees indexed	Positive reactors
	Number	Number
Jonathan/Clark/Columbia	3	2
Jonathan/EM IX/Columbia	3	3
Jonathan/EM VII/Columbia	3	2
Jonathan/K 41/Columbia	3	2
Jonathan/Muzalma/Columbia	3	2
Jonathan/EM IX/Red Del	3	2
Gold. Del./Clark/Columbia	3	3
Gold. Del./EM IX/Columbia	3	3
Gold. Del./EM IX/Gold. Del	3	3
Gold. Del./EM VII/Columbia	3	3
Gold. Del./K 41/Columbia	3	3
Gold. Del./EM IX/Sharon	3	1
Richard/EM IX/Prairie Spy	3	1
Jonadel/EM IX/Columbia	3	3
Jonadel/EM VII/Columbia	3	2
Jonadel/Clark/Columbia	3	2
Red Del./Clark/Columbia	3	0
Red Del./EM IX/Columbia	3	3
Red Del./EM VII/Columbia	3	2
S.R. Del./K 41/Columbia	3	2
S.R. Del./Muzalma/Columbia	3	2
S.R. Del./EM IX/S.R. Del	3	2
S.R. Del./EM IX/Prairie Spy	3	3
Winesap/Clark/Columbia	3	3
Winesap/EM IX/Columbia	3	2
Winesap/EM VII/Columbia	3	2
Winesap/K 41/Columbia	3	1
Winesap/Muzalma/Columbia	3	3
McIntosh/EM IX/Columbia	3	1
McIntosh/Clark/Columbia	3	0
McIntosh/EM VII/Columbia	3	2
Lodi/Clark/Early Red Bird	3	3
Lodi/EM IX/Victory	3	2
R. I. Greening/EM I	3	3
North. Spy/EM I	3	1
Cortland/EM I	3	3
Gold. Del./Muzalma/Ea. Red Bird	3	2
Jonathan/EM I	3	3
McIntosh/EM I	3	3
Red Del./EM I	3	3

(a) Additional indexings on R12740-72 included in Tables 2 and 4.

Stem Pitting in Relation to Chlorotic Leaf Spot

All the components of varieties, interstocks, and rootstocks were examined for stem pitting in the orchard in June, 1960, by peeling back a strip of bark approximately one inch wide and two inches long to expose the wood. Rough pitted wood was positive evidence of stem pitting and smooth wood was negative evidence. Most stem pitting was definite but a few components showed only minor traces. Of all the components included in the variety/interstem/rootstock combinations, only Virginia Crab, 0-524/Delcon, Alnarp 2, Golden Delicious and an occasional Hopa, Columbia, or Dolgo seedling showed that they were indicators for stem pitting.

To our knowledge this is the first instance where O-524 was found to show stem pitting. The trees containing O-524 as an interstock offered the largest and most uniform series of trees for a correlation of the stem-pitting and chlorotic-leaf-spot association. This comparison is shown in Table 2 and summarized in Table 3. Stem pitting

TABLE 2—Chlorotic-leaf-spot and stem pitting reactions obtained from double-worked apple trees containing Ottawa-524 as an interstock

Tree	Combination	Chlorotic leaf spot	Stem pitting		
			Scion	Inter-stock	Root-stock
1-1A	Jonathan/O-524/Bedford	+	−	−	−
1-1B	Jonathan/O-524/Bedford	+	−	−	−
1-1C	Jonathan/O-524/Bedford	−	−	−	−
1-2A	Jonathan/O-524/Columbia	−	−	−	−
1-2B	Jonathan/O-524/Columbia	−	−	−	−
1-2C	Jonathan/O-524/Columbia	−	−	−	−
1-3A	Jonathan/O-524/Dolgo	−	−	−	−
1-3B	Jonathan/O-524/Dolgo	−	−	+	−
1-3C	Jonathan/O-524/Dolgo	+	−	+	−
1-4A	Jonathan/O-524/Hopa	−	−	−	−
1-4B	Jonathan/O-524/Hopa	+	−	+	−
1-4C	Jonathan/O-524/Hopa	+	−	+	−
1-12A	Red Del./O-524/Bedford	−	−	+	−
1-12B	Red Del./O-524/Bedford	+	−	+	−
1-12C	Red Del./O-524/Bedford	−	−	+	−
1-13A	Red Del./O-524/Columbia	+	−	+	−
1-13B	Red Del./O-524/Columbia	+	−	+	−
1-13C	Red Del./O-524/Columbia	+	−	+	−
2-1A	Red Del./O-524/Dolgo	−	−	−	−
2-1B	Red Del./O-524/Dolgo	+	−	+	+
2-1C	Red Del./O-524/Dolgo	−	−	+	−
2-2A	Red Del./O-524/Hopa	−	−	−	−
2-2B	Red Del./O-524/Hopa	+	−	+	−

TABLE 2—Concluded

Tree	Combination	Chlorotic leaf spot	Stem pitting		
			Scion	Inter-stock	Root-stock
2-2C	Red Del./O-524/Hopa	−	−	−	−
2-11A	Gold. Del./O-524/Bedford	+	tr.	+	−
2-11B	Gold. Del./O-524/Bedford	+	tr.	+	−
2-11C	Gold. Del./O-524/Bedford	+	tr.	+	−
2-12A	Gold. Del./O-524/Columbia	+	tr.	+	−
2-12B	Gold. Del./O-524/Columbia	+	−	+	−
2-12C	Gold. Del./O-524/Columbia	+	tr.	+	−
2-13A	Gold. Del./O-524/Dolgo	−	−	−	−
2-13B	Gold. Del./O-524/Dolgo	+	tr.	+	−
2-13C	Gold. Del./O-524/Dolgo	−	−	+	−
3-1A	Gold. Del./O-524/Hopa	−	−	+	−
3-1B	Gold. Del./O-524/Hopa	+	tr.	+	+
3-1C	Gold. Del./O-524/Hopa	−	−	−	−
3-9A	Gold. Del./O-524/Sharon	−	−	−	−
3-9B	Gold. Del./O-524/Sharon	−	−	−	−
3-9C	Gold. Del./O-524/Sharon	−	−	−	−
3-12A	Winesap/O-524/Bedford	−	−	−	−
3-12B	Winesap/O-524/Bedford	+	−	−	−
3-12C	Replant (not included)				
3-13A	Winesap/O-524/Columbia	−	−	−	−
3-13B	Winesap/O-524/Columbia	−	−	−	−
3-13C	Winesap/O-524/Columbia	−	−	−	−
4-1A	Winesap/O-524/Dolgo	−	−	−	−
4-1B	Winesap/O-524/Dolgo	−	−	−	−
4-1C	(tree missing)				
4-2A	Winesap/O-524/Hopa	−	−	−	−
4-2B	Winesap/O-524/Hopa	−	−	−	−
4-2C	Winesap/O-524/Hopa	−	−	−	−
5-2A	Richard/O-524/Virginia	+	−	+	+
5-2B	Richard/O-524/Virginia	+	−	−	−
5-2C	Richard/O-524/Virginia	−	−	−	−
5-11A	Jonadel/O-524/Columbia	−	−	−	−
5-11B	Jonadel/O-524/Columbia	−	−	−	−
5-11C	Jonadel/O-524/Columbia	−	−	−	−

of the O-524 interstock is illustrated in Fig. 2. Of the 28 trees showing either the chlorotic-leaf-spot or the stem-pitting reaction, 14.3 percent gave the chlorotic-leaf-spot reaction without showing stem pitting, while 21.4 percent showed stem pitting without giving a chlorotic-leaf-spot reaction. From these results it would appear that chlorotic leaf spot and stem pitting are the result of different virus entities.

Presented in Table 4 are the reactions of the trees containing other stem-pitting components in their makeup. These varieties, Robin, A 2 and Delcon are shown sensitive to stem pitting by others (Keane and

TABLE 3—A summary of Chlorotic-leaf-spot and stem pitting reactions of trees that contained Ottawa-524 as an interstock

Symptoms expressed		Trees reacting	
Chlorotic leaf spot	Stem pitting	Number	Percent
+	−	4	14.3
−	+	6	21.4
+	+	18	64.3
		Totals 28	100.0

Welsh 1960, McCrum and Hilborn 1960, Millikan and Guengerich 1960). The Robin did not show stem pitting in these investigations. It may be coincidental that the particular varietal isolates used in combination with Robin were free of the virus. However, in one instance, the Columbia rootstock was severely stem pitted even where Robin was used as an interstock.

Delcon, used in a series of three trees, showed a definite but mild stem pitting. This was associated with only a trace of stem pitting of Virginia Crab on two trees and none on the third tree. Nine Delcon

Fig. 2. Bark cutaway showing, right, severe stem pitting on O-524 interstock and trace of stem pitting on Golden Delicious above the bud union; and left, severe stem pitting on O-524 interstock and no stem pitting on Red Delicious above the bud union.

trees growing elsewhere in the orchard but not included in this experiment, also showed the same type of pitting. The Delcon pitting will be investigated further to determine whether this lack of virulence is consistent.

TABLE 4—Reactions of other tree combinations with stem-pitting indicators

Tree	Components	Chlorotic leaf spot	Stem pitting		
			Scion	Inter-stock	Root-stock
1-5A	Jonathan/Robin/Columbia	−	−	−	+
1-5B	Jonathan/Robin/Columbia	−	−	−	−
1-5C	Jonathan/Robin/Columbia	−	−	−	−
2-3A	Red. Del./Robin/Columbia	−	−	−	−
2-3B	Red. Del./Robin/Columbia	−	−	−	−
2-3C	Red. Del./Robin/Columbia	−	−	−	−
3-2A	Gold. Del./Robin/Hopa	−	−	−	−
3-2B	Gold. Del./Robin/Hopa	−	−	−	−
3-2C	Gold. Del./Robin/Hopa	−	−	−	−
3-10A	Gold. Del./Robin/Sharon	−	−	−	−
3-10B	Gold. Del./Robin/Sharon	−	−	−	−
3-10C	Gold. Del./Robin/Sharon	+	−	−	−
5-5A	Richared/Robin/Virginia	−	−	−	−
5-5B	Richared/Robin/Virginia	−	−	−	−
5-5C	Richared/Robin/Virginia	−	−	−	−
5-6A	Richared/A2/Gold. Del	+	−	−	−
5-6B	Richared/A2/Gold. Del	+	−	−	−
5-6C	Richared/A2/Gold. Del	+	−	+	−
5-7A	Delcon/EM IX/Virginia sdlg	−	+	−	tr.
5-7B	Delcon/EM IX/Virginia sdlg	+	+	−	tr.
5-7C	Delcon/EM IX/Virginia sdlg	−	+	−	−
5-3A	Richared/EM IX/Virginia sdlg	+	−	−	+
5-3B	Richared/EM IX/Virginia sdlg	+	−	−	+
5-3C	Richared/EM IX/Virginia sdlg	+	−	−	+
5-9A	Lodi/Robin/Fireside	−	−	−	−
5-9B	Lodi/Robin/Fireside	+	−	−	−
5-9C	Lodi/Robin/Fireside	+	−	−	−
5-12A	Jonadel/Robin/Columbia	−	−	−	−
5-12B	Jonadel/Robin/Columbia	−	−	−	−
5-12C	Jonadel/Robin/Columbia	−	−	−	−
4-3A	Winesap/Robin/Columbia	replant not included			
5-3B	Winesap/Robin/Columbia	−	−	−	−
5-3C	Winesap/Robin/Columbia	−	−	−	−
4-9A	S.R. Winesap/A2/Early Red Bird	−	−	−	−
4-9B	S.R. Winesap/A2/Early Red Bird	−	−	−	−
4-9C	S.R. Winesap/A2/Early Red Bird	−	−	−	−
4-10A	S.R. Winesap/A2/Prairie Spy	−	−	−	−
4-10B	S.R. Winesap/A2/Prairie Spy	+	−	−	−
4-10C	S.R. Winesap/A2/Prairie Spy	−	−	−	−
4-13A	McIntosh/Robin/Columbia	+	−	−	−
4-13B	McIntosh/Robin/Columbia	−	−	−	−
4-13C	McIntosh/Robin/Columbia	−	−	−	−

Rubbery-Wood Reactions

One Winesap tree showing excessive swelling at the junction of the limbs and trunk (often referred to as "bottle-neck") was indexed on Hopa seedlings and on one Lord Lambourne tree in the winter of 1959. One of three Hopa seedlings showed droopy, limber branches in the greenhouse in 1960 and the Lord Lambourne showed typical rubbery-wood symptoms in the field in August 1960. Further investigations on the rubbery-wood virus content of the other trees in this orchard is in progress.

SUMMARY

From indexing 215 double- and single-worked apple trees, 119 trees or approximately 56 percent transmitted the chlorotic-leaf-spot syndrome to the indicator R12740-7A. Stem pitting was found only on trees that included Virginia Crab, Delcon, O-524, Alnarp 2, Golden Delicious and an occasional seedling root in the stock/scion combination. Stem pitting and chlorotic leaf spot appear to be caused by different virus entities. Differences in the severity of stem pitting was observed. The first demonstration of stem pitting of O-524 is reported. The Winesap variety used in these tests did not induce stem pitting. One random indexing from a Winesap tree showed definite rubbery-wood symptoms on a Hopa seedling and a Lord Lambourne tree.

The effect of the viruses on the growth and yield in this five-year-old orchard have not yet been evaluated.

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STORING AND HANDLING PEA BEANS[1]

By JOHN S. PERRY and CARL W. HALL

DEPARTMENT OF AGRICULTURAL ENGINEERING

BACKGROUND

MICHIGAN HAS RANKED FIRST in the United States in the production of field beans during the last 5 years with an average production of 4,927,000 bags (100-pound clean basis). A new high of 5,974,000 bags was produced in 1959. The value of the field beans produced in Michigan during 1955, 1956, and 1957, was $31.3, $35.6, and $28.1 million, respectively. About 90 to 95 percent of the field beans grown in Michigan are of the pea (navy) bean varieties. This constitutes over 95 percent of the pea beans produced in the United States. By far the majority of these are retailed as canned beans, while a smaller percentage is sold as dry packaged beans, and some exported to other countries.

Pea beans in Michigan have traditionally been harvested by cutting or "pulling" of the plants, stacking to dry and threshing with a stationary threshing machine. Pea beans harvested in this way are usually dry and in good storage condition. Because of savings in labor and other costs, combine harvesting of pea beans has now become almost universal.[2] Unfortunately, combine harvested beans are less likely to be uniformly dry and in good storage condition.

RESEARCH IN STORING

Since the harvesting of pea beans is completed in only a few weeks, it is necessary to store large quantities of pea beans in bulk until they can be graded and sorted. The storage of processed or graded bagged beans is also necessary to meet marketing require-

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[2] McColly, H. F. (1958). Harvesting edible beans in Michigan. ASAE Trans. 1:68-71, 75.

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ments while maintaining continuous processing operations. The deterioration of quality of pea beans in bulk storage is usually evidenced by localized moisture accumulation in the surface layers and the subsequent development of mold growth, and by hotspots within the bulk. In the storage of bagged beans, shrinkage and mold growth are of most concern.

Initial Studies

Initial work in the storage of pea beans consisted of observing commercial storage conditions, and of establishing changes in quality of beans in these storages and under controlled laboratory storage conditions.[3] The commercial storage of bagged pea beans was investigated by recording the temperature and humidity of the air in six bean warehouses and comparing with outside weather conditions. Samples were removed periodically from the beans in storage for moisture analyses, fat acidity determinations, and mold counts.

Laboratory studies consisted of observing the deterioration of pea beans stored at 40° F., 60° F., and 85° F., and at 52 percent, 75 percent, and 90 percent relative humidities. Changes in moisture content, fat acidity, and mold counts were observed.

Temperatures inside the warehouses varied with the outside temperatures, though less fluctuation was noted in well-insulated warehouses. Moisture analyses indicated that beans exposed to the atmospheric conditions normally found in commercial warehouses can be expected to assume a moisture content of 14 to 16 percent during the first 6 months of the calendar year, and a moisture content of about 12 to 14 percent during the remainder of the year. Fluctuations in fat acidity were observed, but did not give any significant indication of quality change. The data on mold counts also varied considerably so that no conclusions could be reached. In general, the well insulated warehouses that offer some protection against violent fluctuations of temperature and humidity were desirable.

In controlled laboratory studies, fat acidity and mold counts were not a sensitive indicator of the deterioration of pea beans. Quality was maintained better at the cooler temperatures of 60° F. and 40° F. and at relative humidities of 52 and 75 percent, rather than at 90 percent. Poor quality beans deteriorated most rapidly.

[3] Thompson, J. A. and J. S. Perry (1956). Storage of pea beans in Michigan and Indiana. Agr. Mkt. Ser. 123. U. S. Dept. of Agr., Washington, D. C., 78 pp.

Detection of Mold Growth

Periodic inspections of bagged pea beans in storage are necessary to determine if mold is growing in the beans. Visual inspection without magnification and testing for the presence of a musty odor is the customary procedure. If mold growth is slight, the beans may be "reprocessed" by polishing and rescreening, then sold for immediate use. A method of detecting the development of mold in beans in storage at the earliest stage possible is desirable so that unnecessary losses can be prevented. Wright,[4] in his studies of the storage of artificially dried grass, concluded that the earliest indications of mold growth are visible mycelium and a musty smell. He observed that the presence of mold mycelium constitutes the most delicate test for mold growth. Mustiness only develops at a later stage of deterioration.

In the grading of pea beans, mustiness is considered a method of detecting mold before it is visible through inspection without magnification. The conclusions by Wright, however, indicate that identfication of mold in the vegetative state is possible before a musty odor becomes apparent. In view of this, the development of a practical method of visibly detecting the initial mold growth on pea beans at an early stage of development was undertaken. The method chosen for investigation involved the inspection with a stereomicroscope of individual pea beans from appropriate samples of beans in storage.

Bagged Beans

An investigation was made to establish if microscopic inspection might be useful in detecting initial mold development on bagged pea beans in storage. Good quality pea beans, selected from carload lots of bagged pea beans being placed in a commercial storage, were attached to covered glass petri dishes (plates) with melted paraffin. Fifty beans were arranged in a plate so that they could be identified and microscopically inspected. Twenty-one test plates were prepared and distributed within and on top of three carload lots of bagged pea beans in the commercial storage. Thermocouples were used to record the temperatures periodically in the lots where samples were located. Temperatures increased from the high thirties to the low sixties during the storage period.

[4] Wright, Norman C. (1941). The storage of artificially dried grass. Jour. Agr. Sci. 31:194-211.

The extent of mold development on the beans in the test plates is indicated in Table 1. None of these beans had evidence of mold growth before being placed in storage, yet an average of 35 percent had developed mold that was visible through miscroscopic inspection at the end of the storage period. Official grade analysis of the three lots when moved did not indicate mold or mustiness. The beans placed on top of the lots were directly exposed to the atmosphere and obviously lost moisture, presumably resulting in the lower percentages of mold development. In obtaining similar data the previous year, it was found that microscopically visible mold growth increased from 0 to 11 percent and from 2 percent to 44 percent on samples of beans in test plates distributed throughout two carload lots of bagged beans in storage. Mold or mustiness was not detected through the usual inspection procedures.

TABLE 1—Percentage of selected pea beans in a commercial bag warehouse developing mold during storage in 1957

Test (*a*)	Percentages after storage (May 29 after 3 months storage) (*b*)			
	Carload lot			Average
	A	B	C	
1	32	43	27	34
2	15	61	0	26
3	22	54	57	44
4	51	45	..	48
5	61	33	..	47
6	31	4	2	12
Grand Average				35
Top of lot	2	0	0	1

(*a*) Fifty individual beans per test plate.
(*b*) Microscopically inspected (12x to 36x).

Since, through the use of microscopic inspection, an appreciable percentage of the beans taken from the lots in storage could be identified as being moldy when mold was not detected by the usual inspection procedures, microscopic inspection offers considerable promise of providing a practical and useful method of detecting initial mold in stored pea beans.

Bulk Stored Beans

Because of the increasing interest in the bulk storage of pea beans, an investigation was directed to establish if microscopic inspections would be useful in detecting the initial mold development in bulk stored pea beans. A flat-type bulk storage was selected in which pea beans were placed in the late fall. During the following summer, the beans were sampled and inspected microscopically. Twenty beans were arbitrarily chosen from 6 samples removed at the 0 to 6-inch depth, and the 18- to 24-inch depth in selected sampling areas. Table 2 lists the results of the inspections.

The data presented indicate that appreciably lower percentages of beans from the 0 to 6-inch depth had developed mold. All of the beans were originally alike, but those in the 0 to 6-inch depth subsequently lost moisture during storage so that less mold developed.

When all beans were moved from storage shortly after the final sampling, some heating of the beans, because of rapid mold growth, was observed in sampling area one. The increases in the percentage of beans showing mold in some of the final samples taken at the 18- to 24-inch depth suggests that other areas would have heated similarly.

TABLE 2—Percentage of moldy pea beans in samples from a bulk storage

Sampling area	Sampling depth	Percentages of moldy beans(*a*)		
		DATE		
	Inches	July 2	July 18	July 26
1	0-6	10	0	5
2	0-6	0	15	0
3	0-6	0	0	0
4	0-6	0	—	—(*b*)
5	0-6	0	5	—(*b*)
6	0-6	0	0	—(*b*)
1	18-24	20	85	100
2	18-24	15	65	45
3	18-24	20	75	100
4	18-24	25	40	100(*c*)
5	18-24	40	85	60(*c*)
6	18-24	20	75	100(*c*)

(*a*) Moisture content at 0 to 6-inch depth was 10 to 13 percent. Moisture content at 18 to 24-inch depth was 17 to 18 percent.
(*b*) Beans moved from area.
(*c*) From sample taken at 30-inch depth.

Mold-Free Storage Life

Pea beans were stored under controlled conditions of moisture and temperature, similar to those found in commercial bean warehouses, to obtain information about how long pea beans will remain in storage without developing mold. The beans were periodically inspected with a microscope to detect the first evidence of mold growth. Good quality pea beans with about 16 percent moisture and essentially free of mold growth were selected for study. To insure the presence of mold spores, several beans covered with actively sporulating molds were well mixed with the selected beans. Groups of 50 beans were attached to petri dishes with melted paraffin so each bean could be identified for inspection.

To reduce contamination of the beans in each dish, the plates were covered with flat glass plates and sealed with melted paraffin. Short glass tubes had been inserted through the sides of the dishes, cemented in position and filled with cotton to permit passage of moisture and air and yet prevent mold spores from passing in or out. Two petri dishes, each containing 50 beans, were stored in relative humidities of 52 percent, 75 percent, and 90 percent, at both 40° F. and 55° F. At these temperatures, beans with about 12 percent, 16.5 percent, and 20 percent are in equilibrium with 52 percent, 75 percent, and 90 percent relative humidities, respectively. Inspections of the plated beans were made before being placed in storage and periodically thereafter as deemed appropriate.

At 40° F., no increases in mold growth were observed under any of the storage conditions. Results of storage at 55° F., presented in Fig. 1, show comparatively rapid increase in the percentages of beans having mold at 4 to 4-1 2 months in 90 percent relative humidity storage. A smaller increase was noted at 7 to 8 months for beans stored at 55° F. and 75 percent relative humidity. No increases in mold were noted in beans stored at 55° F. and 52 percent relative humidity.

Many factors will probably influence the mold-free storage life of pea beans. Temperature and humidity may determine the types of molds growing. The previous history of the beans will influence storage condition. However, the data presented show that through use of microscopic inspection procedures, a practical estimate of the mold-free storage life of pea beans can be established to serve as a guide in predicting how long pea beans in storage will remain in an acceptable condition.

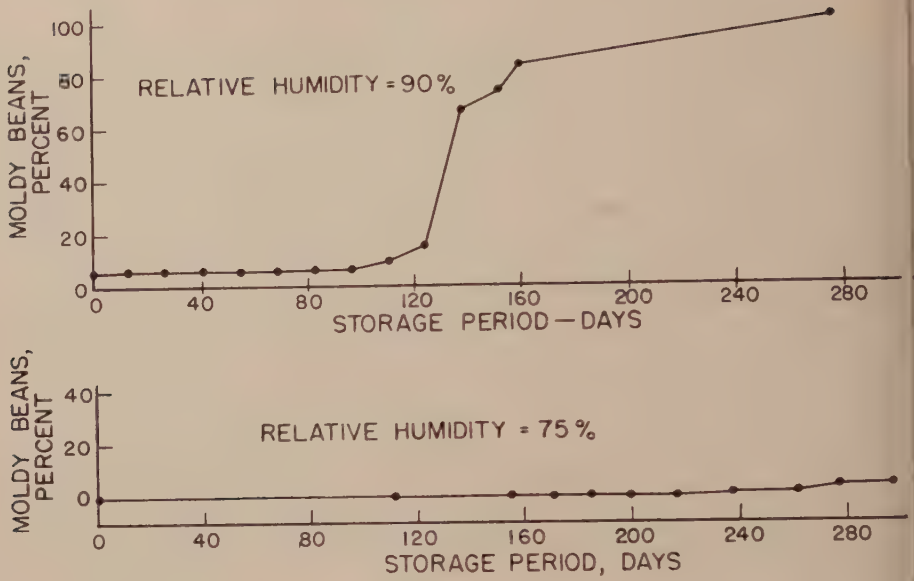

Fig. 1. Mold-free storage life of pea beans: percentages of beans becoming moldy during storage at 55° F.

RESEARCH IN HANDLING

The movement of pea beans from the producer through marketing channels to the consumer requires such handling operations as elevating, conveying, sorting, cleaning, etc. Unfortunately, pea beans are apt to split or develop cracked seed coats from these handling operations.[5] Though the damage is usually small in any particular handling operation, many such operations are involved in marketing beans and losses can be quite severe. If the beans are unusually dry, careful handling is particularly necessary to avoid excessive losses.

Conveyor Studies

The operation of an enclosed screw-type conveyor was studied under laboratory conditions to establish the damage to pea beans resulting from its use. Five hundred pounds of choice hand-picked pea beans with 15.5 percent moisture content at about 75° F. were selected. They were passed repeatedly through a 21-foot belt-driven,

[5] Perry, J. S. (1959). Mechanical damage to pea beans as affected by moisture, temperature, and impact loading. Thesis for Ph.D. degree, Mich. State Univ., East Lansing. (unpublished).

free-floating screw-type conveyor of 6-inch diameter, operating at 400 to 500 rpm. Conveyor operation at the following inclines was studied: (1) horizontal, (2) 15 degrees with horizontal, and (3) 28 degrees with horizontal. A composite of samples was taken initially, then at the discharge of the conveyor during each succeeding test run for analyses of splits and cracked seed coats. Gouge marks, which presumably occurred when the edge of the screw rubbed against beans, were also observed.

When the conveyor was horizontal, the beans moved through it easily and no increase in cracked seed coats or splits could be measured. The average increase of cracked seed coats per test run at 15 and 28° F. was 1.1 percent and 1.5 percent, respectively. No significant increase in splits was observed in either case. Though the results of these and similar tests will vary with different lots of beans, moisture content, temperature, etc., it seems logical that representative values can be established for various handling operations.

Experimental Handling Damage

Special precautions in handling are often necessary when beans are unusually dry. During extended periods of cold weather, processing must often be halted because increased damage develops when beans are cold. Experience has also indicated that the dropping of the beans in bins and silos is particularly damaging. To investigate some of the factors influencing this damage, a standard drop test procedure was established to simulate this commercial handling procedure so that the resulting damage could be related to that occurring under actual handling conditions. Samples of 600 beans each were dropped as a group from one of several heights onto beans of about 18 percent moisture content.

All experimental beans were originally from the same carefully-selected lot which was screened for uniformity and machine sorted to remove defects. No splits and essentially no cracked seed coats were present in the lot. Samples of pea beans at various moisture contents were dropped 11-1/4 feet, 22-1/2 feet, or 45 feet at 25° F., 40° F., 55° F., and 70° F. The samples were subsequently carefully inspected for splits and cracked seed coats. The results of the analyses of some of the data are presented in Fig. 2. Each point represents the average of four samples of 14 percent moisture and four samples of 16 percent moisture.

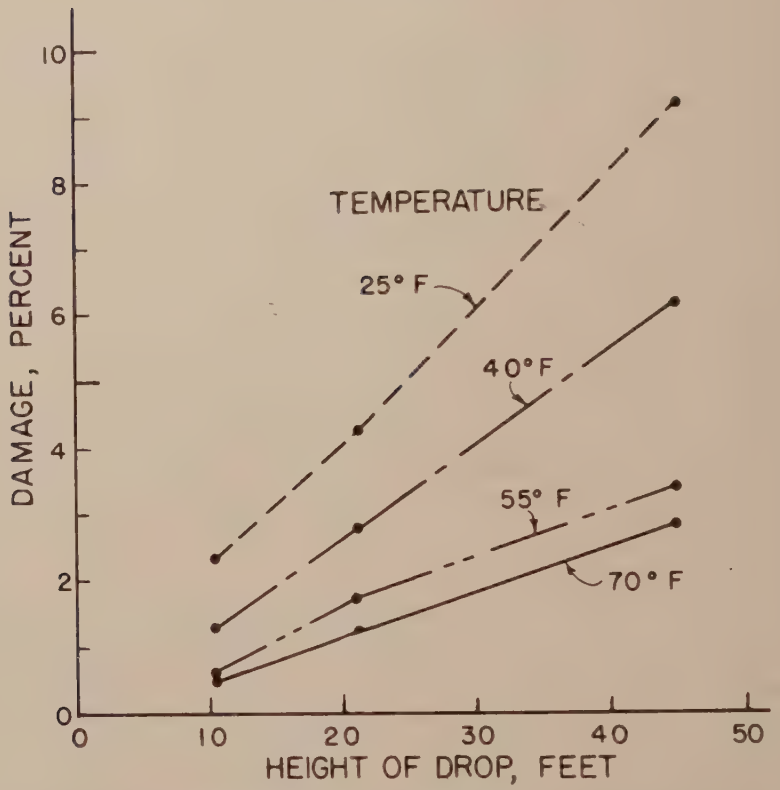

Fig. 2. Experimental damage to pea beans: combined averages for 14 percent and 16 percent moisture pea beans at several temperatures when dropped from selected heights.

Data plotted essentially represent checked seed coats. In dropping 14 percent moisture pea beans from a 45-foot height, 0.7 percent and 0.4 percent splits were experienced at 25° F. and 40° F., respectively. At the higher temperatures and lower drop heights damage in the form of splits was invariably less than 0.1 percent. Negligible splits were experienced with 16 percent moisture pea beans regardless of temperature and height of drop.

Within the selected range of temperatures and heights of drop, increasing the temperature by 30° F. to 70° F. reduced damage at least one-half. Since the experimental beans were of excellent quality, the values presented in Fig. 2 could quite logically be considered as conservative estimates of damage that will occur to commercially

handled pea beans that are dropped under comparable conditions of moisture, temperature, and height. It is also logical to expect that whatever damage might occur can be altered, in proportions similar to those observed experimentally, by adjusting bean temperatures. For example, increasing the temperature 30° F. could be expected to reduce the damage by one-half.

As the height of drop increased, the percent damage increased. In this particular case the damage seems directly proportional to height of drop at any of the experimental temperatures. For example, when the height of drop was doubled, the resulting damage doubled. This relationship may be approximated for other lots of beans of good quality and relatively free of damage. The relationship cannot be expected to hold for beans that have appreciable damage initially.

The development of cracked seed coats is of particular importance because cracked beans are likely to become splits much more easily than sound beans during handling operations. To evaluate this tendency, two lots of pea beans, one consisting of beans with cracked seed coats and the other of beans with no cracked seed coats, were compared by dropping 45 feet. An average of 11.6 percent splits developed in four samples of the beans with cracked seed coats, whereas an average of 0.8 percent splits developed in four samples of the sound beans.

CONCLUSIONS

1. In both laboratory and commercial warehouse studies, fat acidity and conventional "mold counts" did not provide a reliable indication of quality deterioration of pea beans.

2. Through miscroscopic inspection it was possible to detect initial mold growth on pea beans in a commercial storage before it was evident through the usual inspection procedures. Observations on selected beans distributed throughout three carload lots of bagged beans in storage indicated that an average of 35 percent had developed mold, though mold was not normally apparent in the lots.

3. Using microscopic inspection, the mold-free storage life of selected pea beans stored at 90 percent relative humidity and 55° F. was found to be about four months. At 75 percent relative humidity, the mold-free storage life was over eight months. The procedure appears to offer a practical way of estimating the safe storage life of pea beans.

4. A 21-foot, portable, screw-type conveyor was found to cause negligible damage to good quality pea beans when operated horizontally. When it was operated at 15 degrees and 28 degrees from horizontal, 1.1 percent and 1.5 percent cracked seed coats, respectively, were observed.

5. In experimentally dropping beans at temperatures from 25° F. to 70° F. to simulate commercial handling procedures, increasing the temperature of the beans by 30° F. (40 to 70° F.) was found to reduce damage, consisting essentially of cracked seed coats, by one-half. Damage to pea beans that were initially free of all defects was roughly proportional to height of drop. An indication of the importance of cracked seed coats was obtained when 11.6 percent splits developed from dropping beans with cracked seed coats, whereas only 0.8 percent splits developed in similar beans free of defects.

OXYGEN REDUCTION IN CA STORAGES:

A Comparison of Water vs. Caustic Soda Absorbers

By I. J. PFLUG

DEPARTMENT OF FOOD SCIENCE

THE ABSORPTION of carbon dioxide from controlled atmosphere (CA) storages, using water as the absorbing medium, is a new development[1] that can simplify and reduce the cost of operating the CA storage; however, the effect of water absorption of carbon dioxide on the room must be clearly established before optimum application of this method can be made.

Carbon dioxide removed from controlled atmosphere (CA) storages by either a water or caustic soda absorption system is replaced by air from outside the storage. In addition to the oxygen added in the air that replaces the carbon dioxide, the water absorption system transfers a small amount of oxygen to the rooms simultaneous with carbon dioxide removal. This difference in the effect of water absorbers, as compared to caustic soda absorbers, has led to speculation that a water type carbon dioxide absorption system will adversely affect the CA operation by greatly lengthening the period required to initially reduce the oxygen content of the room to the 3 percent needed for proper storage of most varieties of apples.

The analysis reported in this paper was made to evaluate the effect of the oxygen transfer of a water type carbon dioxide absorber on the time required for CA rooms to develop the desired atmosphere of 3 percent oxygen. The effect of the leakage rate and degree of space utilization on the rate of oxygen reduction were also evaluated. This analysis of CA room operation where water and caustic soda carbon dioxide absorption systems are compared under transient conditions is an extension of the steady-state analysis of Pflug and

[1]Palmer, Ralph (1959). Special report to CA storage operators. American Fruit Grower 79: 20-21.

ARTICLE 43-48

Dewey[2],[3] where only caustic soda was used for the absorption of carbon dioxide.

The operation of a CA storage is influenced by many variables. The variables considered with their symbols and units are listed below:

	Symbols	*Units*
Storage room volume (gross)	V	$ft.^3$
Quantity of fruit in storage	B	bushels
Space factor	$Z = \frac{V}{B}$	$\frac{ft.^3}{bu}$
Respiration rate	r	$\frac{ft.^3\ O_2 \text{ consumed}}{1000 \text{ bu. day}}$
Oxygen level in storage	Y	$\frac{ft.^3\ O_2}{ft.^3 \text{ atmosphere}}$
Controlled carbon dioxide level in storage	c	$\frac{ft.^3\ CO_2}{ft.^3 \text{ atmosphere}}$
Leakage or ventilation rate	x	$\frac{\text{air changes (based on empty room volume)}}{24 \text{ hours}}$
Temperature	T	°F.
Oxygen in standard atmosphere		$\frac{0.21\ ft.^3}{ft.^3 \text{ atmosphere}}$
Carbon dioxide in standard atmosphere		$\frac{0.0003\ ft.^3}{ft.^3 \text{ atmosphere}}$
Bushel of apples		45 lb.
Time	t	days
Oxygen diffusion ratio	w	$\frac{ft.^3\ O_2 \text{ added}}{ft.^3\ CO_2 \text{ removed}}$

The oxygen level Y_t of a CA storage at any time t is given by the equation :

$$Y_t = 0.21 - \int_0^t \frac{dO_2}{dt} \qquad (1)$$

The rate of change of the oxygen level of the CA storage atmosphere is a function of: the respiration rate which is in turn a function of

[2]Pflug, I. J. and D. H. Dewey (1955). Controlled-atmosphere storage. Agr. Engineering 35: 171-172.

[3]_____ (1956). A theoretical relationship of the variables affecting the operation of controlled atmosphere storage rooms. Mich. Agr. Expt. Sta. Quart. Bul. 39: 353-359.

time, storage temperatures, and the oxygen level; the initial amount of oxygen per unit of fruit; the amount of oxygen added through leakage; and the amount of oxygen added when carbon dioxide is removed from the storage.

$$\frac{dO_2}{dt} = \frac{r[f(t)] - O_2 \text{ added through leakage } f(Y) - O_2 \text{ added through } CO_2 \text{ adsorption } f(c, Y)}{\text{volume of atmosphere}} \quad (2)$$

The method of finite differences was used to evaluate equation (2).

$$Y_t = 0.21 - \sum_{O \rightarrow t \text{ days}} \frac{\Delta O_2}{\text{day}} \quad (3)$$

The change in oxygen level was then evaluated on a day basis:

$$\frac{\Delta O_2}{\text{day}} = \frac{r - O_2 \text{ added per day through leakage and carbon dioxide removal}}{\text{volume of atmosphere}} \quad (4)$$

The volume of atmosphere in the storage room was calculated assuming that only the solid and liquid portions of the apple and the solid volume of the crate take up space and that the apple is 15 percent carbohydrate solid and 85 percent water for liquid. A 15 percent sugar solution has a density of 66.2 lb./ft.^{3}; therefore, 45 lb. of apples will occupy a net volume of 0.68 ft.^{3}. It was estimated that the crate or box has a solids volume of 0.06 ft.^{3} per bu. of apples. The volume of gas per bushel of apples will be $(Z - 0.74)\frac{\text{ft.}^3}{\text{bu}}$ and the volume of atmosphere per 1000 bu. will be $1000\ (Z - 0.74)\ \frac{\text{ft.}^3}{\text{bu}}$. Since the quantity of atmosphere leakage is a function of the CA storage room as a whole, the leakage rate was considered as xZ per bushel or 1000 xZ per 1000 bushels rather than a function of the net atmosphere per bushel.

Respiration Rate

In Fig. 1, the respiration rate is shown as a function of time for McIntosh apples in CA storage at about 36° F. where the CA storage will develop a 3 percent oxygen level in 15 to 20 days. This curve is the interpretive result of a number of measurements of this elusive variable which is a function of not only time after sealing the CA storage but temperature of the storage, the harvest maturity of the fruit, and other fruit characteristics influenced by factors such as soil fertility level and growing season. The actual average respiration rate of Michigan McIntosh apples should not vary more than 10 percent from the curve in Fig. 1.

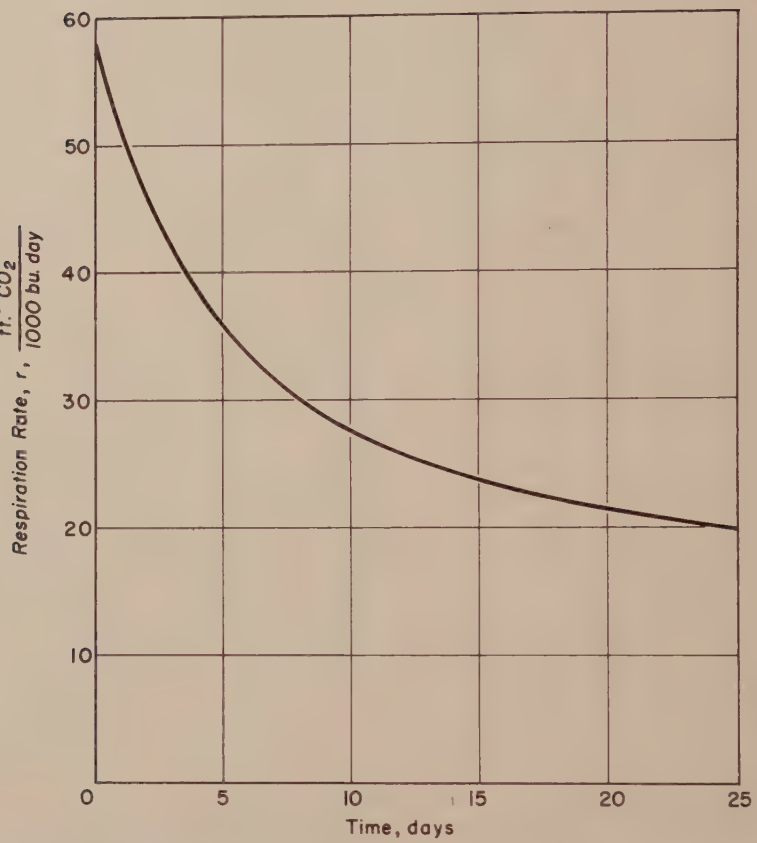

Fig. 1. Respiration curve for McIntosh apples at about 36° F.

Figure 2 shows the effect of carbon dioxide level and oxygen level on the ratio of cu. ft. of oxygen added by the water absorption system per cu. ft. of carbon dioxide removed. Figure 2 was prepared using oxygen and carbon dioxide equilibrium data obtained from the *Handbook of Chemistry and Physics*[4] and assuming equal oxygen and carbon dioxide absorption and desorption coefficients.

Air Leakage

The oxygen gain of a CA storage room per day (24 hr.) was shown by Pflug and Dewey[3] to be Vx (0.21 – y) which is equal to BZx (0.21 – y). The 1000 bushels will produce an oxygen gain through air leakage of 1000 Zx (0.21 – y).

[4]*Handbook of Chemistry and Physics* 39th Ed. (1957). Chemical Rubber Publishing Co., Cleveland, Ohio.

Carbon Dioxide Removal, Caustic Soda

Fruit respiration will produce a volume of carbon dioxide equal to the volume of oxygen consumed. A part of this carbon dioxide (1000 Zxc) will be dispelled by the air leakage. The remainder (r – 1000 Zxc) must be removed from the CA storage by absorption. During absorption of carbon dioxide from the CA storage, a volume of air equal to the volume of carbon dioxide removed will be drawn into the storage room in addition to the air entering by normal leakage. This air drawn in the room to replace carbon dioxide will contain 0.21 oxygen.

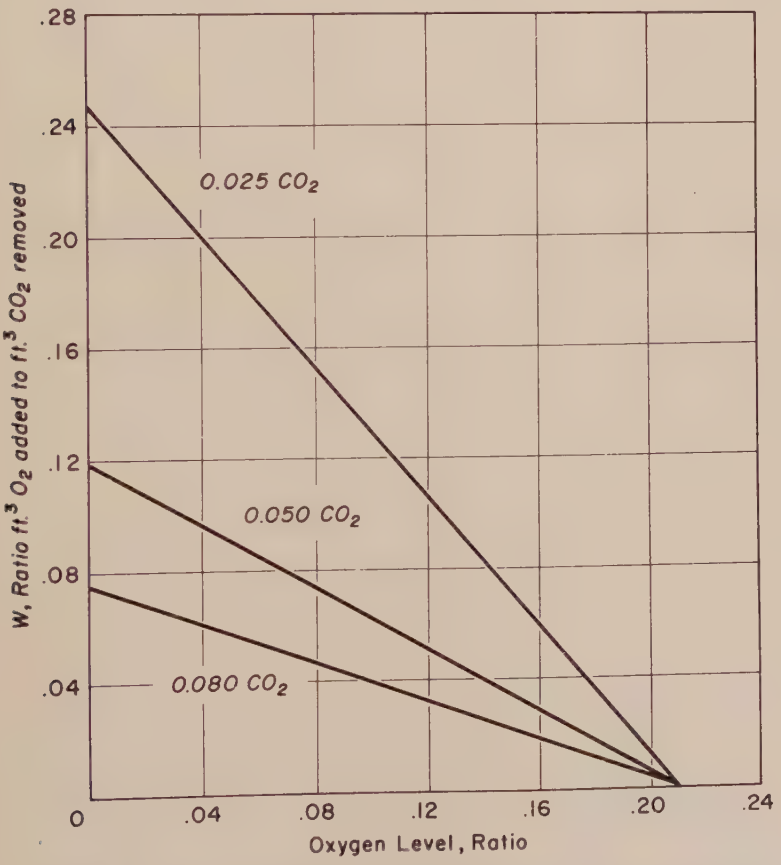

Fig. 2. Graph showing the ratio of cubic feet of oxygen added by water absorption system per cubic foot carbon dioxide removed for carbon dioxide levels of 0.025, 0.050, and 0.080.

Carbon Dioxide Removal, Water Absorption

During the water absorption of carbon dioxide, oxygen moves through the absorption system from the outside area of high oxygen concentration to the inside of the room where there is a low concentration of oxygen or from outside to inside the room. Figure 2 shows the relationship of oxygen added to carbon dioxide removed as a function of room oxygen level and carbon dioxide level. Since the volume of carbon dioxide to be removed is a function of the respiration rate, the amount of oxygen added per 1000 bu. through carbon dioxide absorption is w (r – 1000 Zxc). The oxygen added is only a fractional portion of the carbon dioxide removed; therefore, a quantity of air equal to the difference between the carbon dioxide removed and the oxygen added will also enter the room.

Summary of Relationships

Caustic Soda Absorption

Oxygen consumed and CO_2 produced $= r = \frac{\text{ft.}^3}{1000 \text{ bu. day}}$

Oxygen added through air leakage $= 1000\ Zx\ (0.21 - Y) = \frac{\text{ft.}^3}{1000 \text{ bu. day}}$

Oxygen added through CO_2 removal $= 0.21\ (r - 1000\ Z_{rc}) = \frac{\text{ft.}^3}{1000 \text{ bu. day}}$

Volume of atmosphere per 1000 bu. $= 1000\ (Z - 0.74) = \text{ft.}^3$

$$\frac{\Delta O_2}{\text{day}} = \frac{0.79r}{1000\ (Z - 0.74)} - \frac{Zx}{Z - 0.74}\ (0.21 - Y - 0.21c)$$

$$Y_t = 0.21 - \sum_{O \rightarrow t \text{ days}} \left[\frac{0.79r}{1000\ (Z - 0.74)} - \frac{Zx}{(Z-0.74)}\ (0.21 - Y - 0.21c)\right] \quad (5)$$

Water Carbon Dioxide Absorption

Oxygen consumed and CO_2 produced $= r = \frac{\text{ft.}^3}{1000 \text{ bu. day}}$

Oxygen added through leakage $= 1000\ Zx\ (0.21 - Y) = \frac{\text{ft.}^3}{1000 \text{ bu. day}}$

Oxygen added by absorber through diffusion $= w\ (r - 1000\ Zxc) = \frac{\text{ft.}^3}{1000 \text{ bu. day}}$

Oxygen added through CO_2 removal $= 0.21\ [r - 1000\ Zxc - w\ (r - 1000\ Zxc)] = \frac{\text{ft.}^3}{1000 \text{ bu. day}}$

Volume of atmosphere per 1000 bu. $= 1000\ (Z - 0.74) = \text{ft.}^3$

$$\frac{\Delta O_2}{\text{day}} = \frac{0.79r\ (1 - w)}{1000\ (Z - 0.74)} - \frac{Zx}{(Z - 0.74)}\ (0.21 - Y - 0.21c - 0.79\ wc)$$

$$Y_t = 0.21 - \sum_{O \rightarrow t \text{ days}} \left[\frac{0.79r\ (1 - w)}{1000\ (Z - 0.74)} - \frac{Zx}{(Z - 0.74)}\ (0.21 - Y - 0.21c - 0.79\ wc)\right] \quad (6)$$

Analysis

Equation 5 for calculating the oxygen level Y can be solved since Z, the space factor and x, the air changes per day are assumed fixed

for any given storage condition. The carbon dioxide level c will vary starting with a ratio of approximately 0.0003 when the room is sealed and rising to a fixed controlled level after a few days. A carbon dioxide ratio of 0.0250, the lowest level used in Michigan CA storages is used in these calculations. The term

$$\frac{Zx}{(Z - 0.74)} \quad (0.21 - Y - 0.21c)$$

in equation 5 was solved as a function of Y for values of Z of 2.5, 3.0, 3.5 and for values of x of 0.01, 0.02 and 0.03 where c was 0.0250. A graph of the f(Y) vs. Y was drawn (Fig. 3) so that values of the function for any value of Y could be quickly determined. In the numerical analysis, the oxygen level Y of the previous day was used to estimate this function for the succeeding day. The equation was evaluated numerically in the form:

$$Y_t = 0.21 - \sum_{O \rightarrow t \text{ days}} [kr - f(Y)] \qquad (7)$$

where k, a constant is $\frac{0.79}{1000\ (Z - 0.74)}$

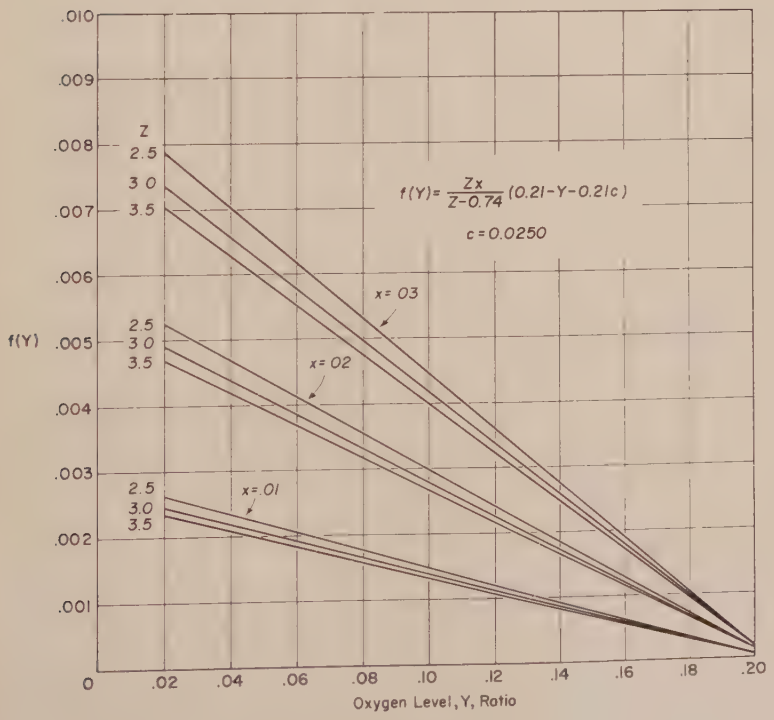

Fig. 3. f(Y) term of equation 5 vs. Y.

Equation 6 was evaluated in the same way as equation 5. The term

$$\frac{Zx}{(Z - 0.74)} \quad (0.21 - Y - 0.21c - 0.79wc)$$

in equation 6 was solved as a function of Y for values of Z of 2.5, 3.0 and 3.5 and for values of x of 0.01, 0.02, and 0.03 where c was 0.0250. Values for w were obtained from Fig. 2. Figure 4 is a graph of the f(Y) vs. Y. Equation 6 was evaluated in the form:

$$Y_t = 0.21 - \sum_{0 \rightarrow t \text{ days}} [kr\ (1 - w) - f(Y)] \qquad (8)$$

The value of (1 – w) was determined using the oxygen level Y for the previous day to obtain w from Fig. 2.

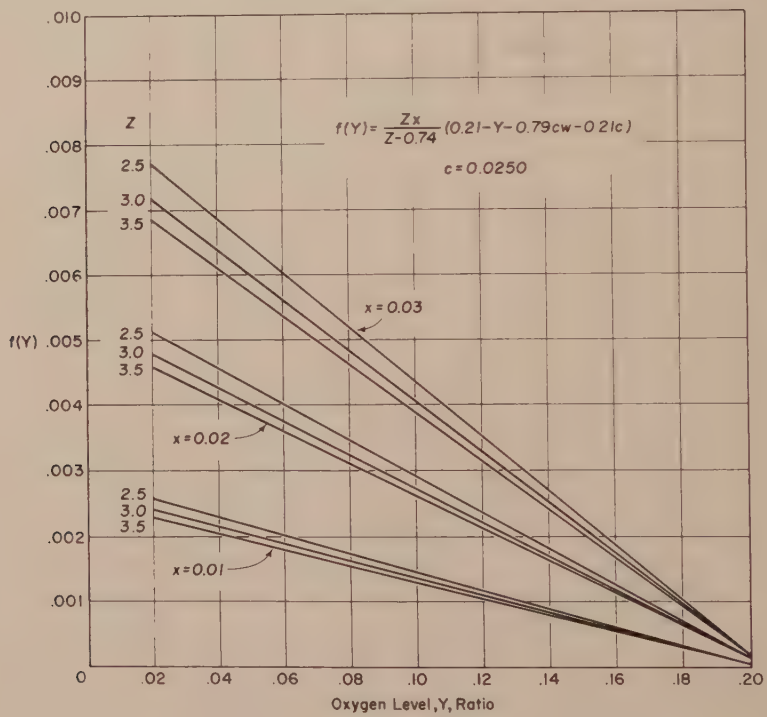

Fig. 4. f(Y) term of equation 7 vs. Y.

Oxygen reduction curves were developed for both water and caustic soda carbon dioxide absorption for several conditions of room fullness, leakage rate and carbon dioxide level using equations 7 and 8. The results in number of days to reduce the oxygen level to 0.030 for a carbon dioxide level of 0.025 are presented in Table 1.

A graphical comparison of the oxygen reduction rates of water vs. caustic soda carbon dioxide absorption, space factor 2.5 and carbon dioxide level 0.025, are shown in Fig. 5 for leakage rates of 0.01 and 0.03 respectively. The effect of space factor on the time required to develop a 3 percent oxygen atmosphere for a 0.01 leakage rate is shown in Fig. 6.

DISCUSSION

The results in Table 1 and in Figures 5 and 6 dramatically show the effect of leakage and fullness on the time required for a CA room to develop the desired atmosphere. A CA storage room using water

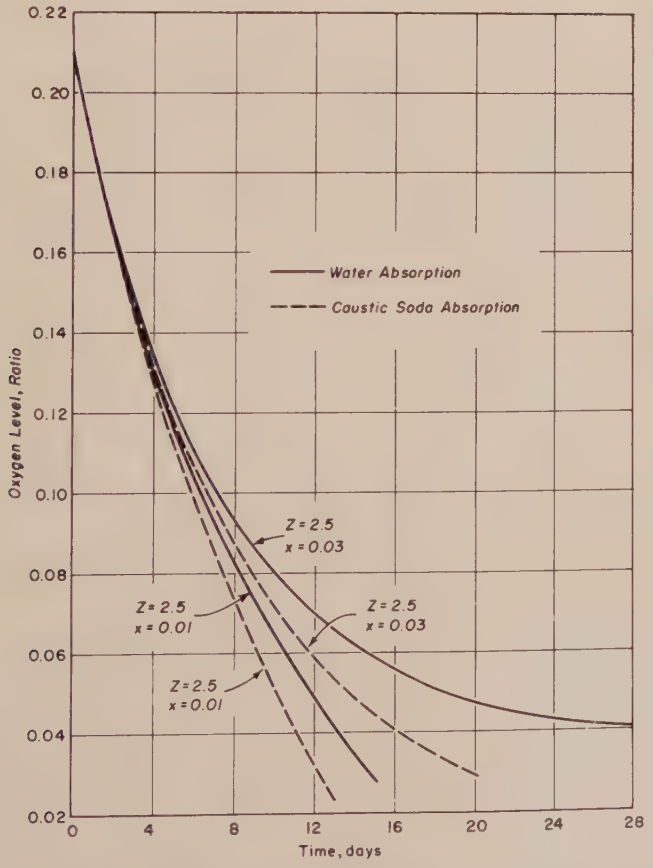

Fig. 5. Oxygen reduction curves for both water and caustic soda carbon dioxide absorption for leakage rates of 0.01 and 0.03 for a space factor of 2.5 and a carbon dioxide level of 0.025.

absorption will take about 20 percent longer to develop a 3 percent oxygen atmosphere than when caustic soda is used as the absorbing medium. In the adequately tight, fully-loaded room this means 2 to 3 additional days are needed. A CA room that is leaky or partially filled with fruit and requiring 25 to 30 days to develop a satisfactory oxygen level of 3 percent, when caustic soda is used for carbon dioxide absorption, is unlikely to develop the desired atmosphere in a permissible length of time when water is employed for carbon dioxide absorption.

An indication of the effect of the leakage rate on the oxygen reduction rate can be obtained from Figures 3 and 4, since the respective

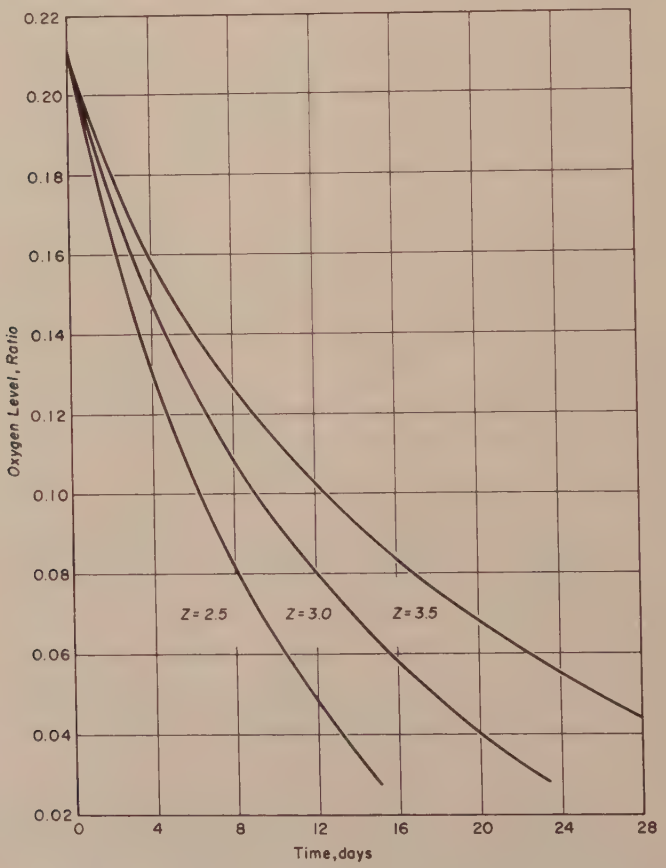

Fig. 6. Oxygen reduction curves for fullness values of 2.5, 3.0, and 3.5 using water absorption of carbon dioxide with a leakage rate of 0.01 and a carbon dioxide level of 0.025.

TABLE 1—Time required for CA storage room to reduce the oxygen level to 0.030, carbon dioxide level 0.025, as a function of type of carbon dioxide absorption system, leakage rate and room fullness

Type of carbon dioxide absorption system	Space factor Z, $\frac{ft.^3}{bu.}$	Days to reduce oxygen level to 0.030			
		Leakage rate, x, air changes per day			
		0	0.01	0.02	0.03
Water	2.5	13	15	20	over 25
	3.0	19	23	over 25	
	3.5	24	over 25		
Caustic soda	2.5	11	13	15	20
	3.0	16	19	25	over 25
	3.5	21	over 25		

functions are oxygen gain values including oxygen gain from carbon dioxide absorption. It is worthwhile to note that the oxygen gain value increases as the oxygen level decreases. Since the respiration or oxygen usage rate (Fig. 1) decreases with time (oxygen level decreases with time in a parallel fashion), the period of maximum oxygen gain occurs when there is minimum oxygen usage. This causes the oxygen reduction curve to tend to become horizontal; the point and degree to which the curve flattens is determined by the space factor and leakage rate.

Room fullness affects the ratio of oxygen consuming fruit to oxygen in the room. For example, a space factor of 2.5 yields a ratio of 1.76 cu. ft. of atmosphere per bushel of fruit. Whereas a space factor of 3.5 yields a ratio of 2.76. If the oxygen usage rate was constant throughout the period in which the oxygen level is being reduced, the time required to develop the desired atmosphere, when the space factor is 3.5, would be 56.8 percent greater than if each bushel occupied only 2.5 cu. ft. of storage space. Actually, the oxygen reduction rate decreases as the oxygen level is lowered, so a much longer time is required with the larger space factor.

SUMMARY AND CONCLUSIONS

The absorption of carbon dioxide from CA storages using water as the absorbing medium is practical for the whole storage season

including the oxygen reduction period. Tight CA rooms completely filled with fruit require only 2 or 3 days longer to develop a 3 percent oxygen atmosphere than similar rooms operated with caustic soda absorbers. CA rooms that are borderline in tightness or partially filled cannot be expected to operate satisfactorily when water absorption systems are used for carbon dioxide removal.

A procedure for numerically calculating the rate of oxygen reduction of the atmosphere of CA storage rooms is presented and used to compare the oxygen reduction rate, when caustic soda and water carbon dioxide absorbers are employed, on rooms of several fullnesses and leakage rates. Only 2 to 3 days of additional time is required for a tight CA room to develop a 3 percent oxygen atmosphere when a water absorber is used in place of a caustic soda absorber for carbon dioxide removal. A greater time differential occurs for rooms that are either leaky or only partially filled with fruit.

JOURNAL ARTICLE ABSTRACTS

Materials Handling – Methods and Labor Requirements

KLEIS, R. W. AND D. E. WIANT

Transactions of the ASAE. 3(2): 140, 141, 142, 144. 1960 (Journal Article 2175 from the Michigan Agricultural Experiment Station)

A study of the materials handling problems on an unbiased sample of 320 typical livestock farms, mechanized to some degree, in the lower two-thirds of Michigan (lower peninsula) indicates that with a fixed size enterprise mechanization can reduce labor requirements effectively only if the labor released is hired labor. On farms where no hired labor is involved the justification of increased mechanization must be based upon:

1. Expanded scale of operation.
2. More intensive production within the existing limits.
3. Relief from drudgery or disagreeable work. It appears that the farms which most logically should consider increased mechanization are those which employ part-time seasonal help.

Particle Size Designation Analysis

NICHOLAS, R. C. AND C. W. HALL

Transactions of the ASAE. 3(2): 111-112. 1960. (Journal Article 2181 from the Michigan Agricultural Experiment Station)

The paper is a critique of fineness modulus and uniformity index as a measure of actual particle size and distribution in sieved material. A mathematical analysis is presented from which comparisons of fineness modulus and uniformity index are made, and in which it can be seen that fineness modulus gives an over-estimation of size. The essential point of the analysis lies in the use of more appropriate weighting factors for the material retained on each sieve. In the case of Tyler sieves with 2:1 ratio openings, the required weighting factors decrease rather than increase as used in fineness modulus determination. Formulas for average particle area and total area are presented, as well as some discussion of appropriate sieve size choice.

Oxidation-Reduction Studies on the Mechanism of B Horizon Formation in Podzols

MCKENZIE, L. J., E. P. WHITESIDE AND A. E. ERICKSON

Soil Sci. Soc. of Amer. Proc. 24: 300-305. 1960. (Journal Article 2224 from the Michigan Agricultural Experiment Station)

Oxidation-reduction potentials *in situ* have been measured in a hydrosequence of soils in the Podzol region of Michigan with variations in time and space. The soils were well drained Kalkaska sand, imperfectly drained Saugatuck sand

and poorly drained Roscommon sand. The distribution of citrate oxidizing organisms and iron oxidizing organisms in horizons of Kalkaska and Saugatuck sands was also studied.

Redox potentials were observed to vary with moisture, temperature and soil horizons. The population of citrate oxidizing organisms decreased with depth and iron oxidizing organisms were isolated from the B_{1r} horizons of both Kalkaska and Saugatuck sands.

The results indicate that certain mechanisms of Podzol formation may be active in the soils studied.

Resistance of Shelled Corn and Wheat to Low Air Flows

SHELDON, WALTER H., CARL W. HALL AND J. K. WANG

Transactions of the ASAE. 3(2): 92-94. 1960. (Journal Article 2456 from the Michigan Agricultural Experiment Station)

The resistance of shelled corn and wheat to air flows ranging from .05 cfm to 4.0 cfm per square foot was measured. The displacement of water within a transparent plastic cylinder equipped with hook gages provided an accurate means of determining the rate of air flow to the grain. Within the limits of these data the resistance to air flow through shelled corn and wheat increases more rapidly than the depth of grain.

The resistance to air flow also increases more rapidly than an increase in air flow. When plotted on log-log paper the factors of resistance for twice the air flow in cfm is a straight line. This line may be extended and used as a convenient tool for extrapolating the resistance to air flow at rates above and below the range of available data. These relationships are explained on the basis of a dimensional analysis for laminar and turbulent flow.

Chromatographic Determination of Cysteic Acid

BANDEMER, SELMA L. AND ROBERT JOHN EVANS

Jour. of Chromatography. 3:431-433. 1960. (Journal Article 2464 from the Michigan Agricultural Experiment Station)

Difficulty was encountered in the determination of cysteic acid with ninhydrin after elution from a resin column, using a Time-Flow fraction-collector. Since the trouble arose from the variable pH obtained on the addition of sodium hydroxide to the eluate, a buffered solution of 2N sodium hydroxide saturated with sodium citrate was used to produce the pH 5.0 required for maximum color development. The calibration for 10 ml. of the tubes collecting the eluate, and the use of a standard cysteic acid curve facilitated the calculation of the cysteic acid concentration in the sample.

The Effect of Various Stresses Upon Histomoniasis in Chickens and Turkeys

WELTER, C. JOSEPH

Poultry Sci. 39: 361-366. 1960. (Journal Article 2466 from the Michigan Agricultural Experiment Station)

Various stress factors were applied to chickens in attempts to increase mortality. Such factors which had no significant effect (5 percent confidence

level) were: starvation, induced anemia, exposure to temperature extremes, concurrent coccidial infections, fowl pox vaccination, cortisone injection and splenectomy.

Proventricular lesions were periodically observed and considered the result of direct contingent migration of the histomonads from the adjacent liver.

Determination of Molybdenum in Plants

BENNE, ERWIN J. AND E. I. LINDEN

Jour. of the Assoc. of Official Chemists. 43: 510-511. 1960. (Journal Article 2486 from the Michigan Agricultural Experiment Station)

This article describes a method for determining molybdenum in plant materials, which the authors have adapted and tested over a period of several years in connection with the program of the Association of Official Agricultural Chemists for the development of Analytical Methods. It is recommended that the method be included in the Ninth Edition of Official Methods of Analysis of the A.O.A.C., which will be published in 1960.

Environmental Influences on Regression Factors for Estimating 305-Day Production from Part Lactations

FRITZ, G. R., L. D. MCGILLIARD AND D. E. MADDEN

Jour. of Dairy Sci. 8: 1108-1117. 1960. (Journal Article 2494 from the Michigan Agricultural Experiment Station)

Cumulative milk and fat production on test day from 11,420 Michigan DHIA-IBM records from 1953 to 1957 were used to derive regression factors for estimating 305-day production from part lactations. The data included 8,993 Holstein, 1,457 Guernsey, 651 Jersey and 319 Brown Swiss lactations.

Linear regression coefficients of total on part lactation within herd-season-lactation-age groups were used to measure the relationship between cumulative production on test day and total production for the first 10 days. Examination of the regression coefficients indicated that season and herd were not important influences on the part to whole relationship. Intra-herd factors for extending incomplete records were developed from the average regression coefficients of total on part lactations within seasons, lactations, and ages for each of the nine cumulative test days.

Correlations between cumulative part and 305-day production ignoring herd differences were not less than 0.7 for the first month, increased steadily as the lactation progressed, and were 0.9 by the fifth test day for all breeds.

Effect of Feeding Escherichia Coli to Turkey Poults and Chicks in the Presence of Certain Antibiotics

WARDEN, W. K. AND P. J. SCHAIBLE

Poultry Sci. XXXIX: 729-734. 1960. (Journal Article 2495 from the Michigan Agricultural Experiment Station)

Two separate four-week battery experiments with Broad Breasted Bronze poults and broiler-type chicks were conducted to determine the effect of crop

inoculations with *Escherichia Coli* cultures in mediating the growth responses to narrow- and broad-spectrum antibiotics.

Two-hundred grams per ton of zinc bacitracin promoted significant growth responses in the presence or absence of bi-weekly inoculations with a trypticase soy broth culture of *Escherichia Coli*, supernatent of an *Escherichia Coli* culture, or centrifuged *Escherichia Coli* cells in saline. None of the coliform inoculation treatments were effective in altering the *Escherichia Coli* population of the digestive tract or the growth pattern of either poults or chicks in the presence of either dietary antibiotic.

Addition of the same level of terramycin also resulted in significant growth improvement in poults, but not in chicks.

Experimental Leptospirosis: The Early Pathogenesis of *Leptospira Pomona* Infection in Young Swine

SLEIGHT, STUART D., ROBERT F. LANGHAM AND RAYMOND L. MORTER

Jour. of Infectious Diseases. 106: 262-269. 1960. (Journal Article 2523 from the Michigan Agricultural Experiment Station)

A controlled experiment using 30 pigs was conducted to study the pathogenesis of *L. pomona* infection in young swine during the 14-day period following inoculation.

Demonstrable microscopic renal lesions were present by day 4. These early lesions consisted primarily of an intertubular leukocytic infiltration with lymphocytes the predominant inflammatory cell. Only minor degenerative changes were observed, and kidney function was apparently normal.

Gross kidney lesions, consisting of grayish-white foci on the cortical surface, appeared on day 7 and were extensive by day 9.

Microscopic brain lesions were present by day 11. The meningoencephalitis was characterized by perivascular lymphocytic infiltrations in the cerebrum.

Hematological values were only slightly altered from normal determinations. Serological and clinical findings substantiated previous experimental evidence.

Swine appear clinically to adapt quite readily to *L. pomona* infection and this further enhances their ability to serve as carrier animals.

Activity Measurements in Water and Clay-Water Systems with Tertiary Electrodes

UEHARA, GORO AND M. M. MORTLAND

Soil Sci. Soc. of Amer. Proc. 24: 261-264. 1960. (Journal Article 2532 from the Michigan Agricultural Experiment Station)

A tentiary amalgam electrode was utilized in the measurement of $CaCl_2$ and Ca++ activities. Activity coefficients from emf data compared favorably with those in the literature. The relative influence of various metal ion salts on the $CaCl_2$ and Ca++ activities followed the sequence Rb>Mg>K>Na>Li for both kaolinite and Wyoming bentonite. The activities of $CaCl_2$ and Ca++ in bentonite-kaolinite mixtures differed from predicted activity values based on pure clay systems.

Parathyroid Hormone-Like Activity in the Sera of Rats with Induced Hyperparathyroidism

BUCKNER, BEVERLY AND JOHN E. NELLOR

Endocrinology. 67: 82-89. 1960. (Journal Article 2538 from the Michigan Agricultural Experiment Station)

Rats fed a calcium-deficient, Vitamin D-free diet for a 20-day period maintained serum calcium levels in the 8 to 11 mg.% range. Parathormone-like activity was biologically assayed in the blood of rats by the eighth day of dietary regime. Parathormone-like activity was assayed by the rise in serum calcium of thyroparathyroidectomized rats following the injection of sera from the hyperthyroid rats.

A comparison of the serum calcium rise in the assay animals induced by the injection of standard "Parathormone", to that induced by the injection of serum, allowed an estimation of 20 to 43 units of "Parathormone Equivalence" per cc. of serum from calcium-deficient rats. A graded parathormone response was obtained by varying the amounts of serum assayed. Parathormone-like activity was not assayable in 1 cc. of sera from normal rats.

Comparative Incidence of Graywall and Internal Browning of Tomato and Sources of Resistance to These Disorders

MURAKISHI, HARRY H.

Phytopathology 50: 408-412. 1960. (Journal Article 2540 from the Michigan Agricultural Experiment Station)

Graywall (GW) and internal browning (IB) occurred together in fields in Michigan in 1958 and caused severe losses. Studies in which both disorders were reproduced simultaneously confirmed that GW and IB have nearly identical symptoms. GW was induced by low light intensity in TMV-free plants, whereas IB was caused by late infection with a strain of tobacco mosaic virus (TMV). Low light also increased the incidence of IB in susceptible varieties. Two GW-resistant varieties, Indian River and Manalucie, were susceptible to IB, but Holmes' and Walter's TMV-resistant breeding lines were resistant to both GW and IB. Assays showed that IB reaction was correlated to TMV reaction. A tobacco-etch-resistant line proved susceptible to IB.

Gas Chromatography as a Means of Detecting Odors in Milk

WYNN, J. D., J. R. BRUNNER AND G. M. TROUT

Food Tech. 14: 248-250. 1960. (Journal Article 2541 from the Michigan Agricultural Experiment Station)

Gas chromatography was utilized to show the effectiveness of vacuum pasteurization as a means for removing the volatile feed flavors from milk. Approximately 85% of the measurable flavor components of milk were removed by the vacuum pasteurization process with a resulting one-to-two point increase in flavor score.

Characteristic gas chromatograms were obtained for the volatiles in milk from cows fed alfalfa silage, onion tops, or beet tops.

Gas chromatography offers a valuable tool for the study of the effectiveness of deodorizing equipment as a means of removing the volatile flavor components of milk.

A Necrotic Pod Streak of Pepper *(Capsicum annum L.)* Caused by Tobacco Mosaic Virus

MURAKISHI, HARRY H.

Phytopathology. 50: 464-466. 1960. (Journal Article 2552 from the Michigan Agricultural Experiment Station)

Necrotic pod streak, previously unreported in pepper *(Capsicum annum L.)* was reproduced experimentally in parallel inoculation tests with virus isolated from diseased pods and with Holmes' distorting strain of tobacco mosaic virus (TMV). Plants inoculated at first flowering usually expressed necrotic pod streaks and stem necrosis in about 4-6 weeks, but inoculation of plants bearing mature pods resulted in an internal pod necrosis. Pod streak symptoms occurred at 28, 22, and 17° C., but only the small-fruited Hungarian Sweet and two other related varieties were susceptible. None of the large-fruited types tested developed pod necrosis. The pepper virus, shown to be a strain of TMV, differed from Holmes' distorting strain in its failure to incite local lesions on Pinto and Scotia bean and from Miller and Thornberry's tomato atypical mosaic virus in thermal inactivation, 93° C for 10 minutes.

Effect of Different Length Chill Periods with Chlortetracycline and Different Holding Conditions on the Shelf-Life of Dressed Fryers

ESSARY, E. O., L. E. DAWSON AND W. L. MALLMAN

Food Technology. 14(6): 286-289. 1960. (Journal Article 2555 from the Michigan Agricultural Experiment Station)

Chicken fryers, chilled from 2 to 24 hours in water and 20 ppm chlortetracycline (CTC) solutions were later held in chip ice or tray-packages until evaluated. Microbiological counts and scores of raw odor were obtained on alternate days after processing and until birds were inedible. No beneficial effect was obtained by CTC treatment up to 10 days storage, however, CTC treatment resulted in lower bacterial counts and more desirable odors after 10 days storage such that acceptable shelf life was extended from 2 to 4 days. Two-hour chill periods resulted in lower bacterial counts and more desirable odors than did 12- and 24-hour periods. Tray packaging resulted in longer shelf life than did ice packing.

Human Energy Expenditures in Handling Baled Hay and Straw in and Around Farm Buildings

HODGES, T. O. AND M. L. ESMAY

Agricultural Engineering. 41: 502-505, 518-519. 1960. (Journal Article 2565 from the Michigan Agricultural Experiment Station)

Human energy expenditure measurements have been neglected in most studies aimed at classifying farm jobs. Time and distance data have been the primary yardsticks in such investigations. Human energy, time, and distance all are needed to describe completely any operation. These three parameters can be used for classifying farm jobs, developing improved work methods, laying out farm buildings, and as guides in the design of machinery and equipment.

This study was directed towards determining quantitatively the human energy expenditures in handling baled materials in and around farm buildings. The total bedding operation with baled straw was broken into component

activities of (1) lifting and stacking bales, (2) carrying bales, (3) dragging bales and (4) shaking and distributing straw over the bedded area. These component activities were investigated under controlled conditions with different subjects in such a way that metabolic work energy expenditures were measured by indirect calorimetry.

Characteristics of Protein Fractions Isolated from the Fat/Plasma Interface of Homogenized Milk

JACKSON, R. H. AND J. R. BRUNNER

Jour. Dairy Sci. XLIII: 912-19. 1960. (Journal Article 2575 from the Michigan Agricultural Experiment Station)

The technique employed to isolate the proteins of the fat-globule membrane of homogenized milk was based on a procedure described by Herald and Brunner for isolating the membrane proteins of non-homogenized milk. Since homogenization results in the alteration of the components constituting the fat/plasma interface in milk, their methods were modified and extended to include a fractionation for milk proteins other than the normal membrane-proteins.

The insoluble membrane-protein, constituting a portion of the normal membrane, was isolated from the homogenized fat-globule membrane. This reddish-brown fraction remained, at least in part, with the fat globule following homogenization.

The soluble membrane-protein of the nonhomogenized fat globule was recovered from preparations of the membrane of homogenized milk. A portion of this protein fraction appeared to be associated electrophoretically with the α-casein oriented at the fat/plasma interface. The remaining portion was recovered from the membrane as an unassociated protein fraction.

Influence of Timing and Insect Biology on the Effectiveness of Insecticides Applied for Control of European Pine Shoot Moth, *Rhyacionia Buoliana*

BUTCHER, JAMES W. AND DEAN L. HAYNES

Jour. of Econ. Entomology. 53: 349-354. 1960. (Journal Article 2577 from the Michigan Agricultural Experiment Station)

Spring and summer field insecticide applications were made to compare the effectiveness of selected chlorinated hydrocarbon and organic phosphate insecticides in control of the European pine shoot moth. Control obtained with spring applications of dimethoate, DDT, and Phosdrin confirmed earlier success with these materials. Guthion, methoxychlor, and Bayer 22408 also showed promise. Evidence that resumption of spring feeding and larval migration may be protracted by weather in a given year suggests that timing of the spring insecticide application should coincide with initial pitch blister ("tent") formation. Results of Sevin, DDT, and dimethoate applications made 7 times between the period of 60 percent adult emergence and the date when 90 percent of the eggs had hatched (summer) give evidence that treatment should be deferred until at least 50 percent of the eggs have hatched. Evidence showing that larvae always feed first in the needles and then in the buds of the tree points up the desirability of having a maximum amount of insecticidal residue present at this time.

Inoculum Production and Seedling Evaluation of Celery for Resistance to Cercospora Apii

MURAKISI, H. H., S. HONMA AND R. KNUTSON

Phytopathology. 50(8): 605-607. 1960. (Journal Article 2584 from the Michigan Agricultural Experiment Station)

Abundant conidia of *Cercospora apii* were obtained on celery leaf-muck soil medium, carrot leaf decoction agar, and carrot root discs. Respective average number of conidia produced per mm^2 of media surface were 80, 53, and 42. Carrot leaf decoction agar was preferred because 2-3 successive crops of conidia could be harvested. When a spore suspension containing 5000-10000 conidia per cc was atomized on susceptible seedlings at the 4-6 leaf stage and the plants incubated 48-72 hours at 100% RH, lesions suitable for disease evaluation resulted after 10-14 days in the greenhouse. The reaction of resistant and susceptible lines and varieties to seedling infection were similar to results with natural infection in the field.

The Influence of "Impulse Buying" or In-the-Store Decisions on Consumers' Food Purchases

SHAFFER, JAMES D.

Jour. of Farm Economics. XLII: 317-324. 1960. (Journal Article 2591 from the Michigan Agricultural Experiment Station)

The purpose of this study was to estimate the influence of "impulse buying" or in-the-store decisions on (1) total food expenditures and (2) the allocation of expenditures among particular foods and food groups.

The basic findings of this study may be summarized as follows:

1. A comparison between anticipated and actual food purchases for a week by individual families showed that less than half of the purchases actually made were anticipated. This indicates that a large percentage of food purchase decisions are made in the store.

2. A comparison between anticipated and actual food purchases for two random population samples showed there was little difference between anticipated and actual purchases for the population as a group. This indicates that total food expenditures and the allocation of expenditures among particular foods and food groups for the population as a whole are not substantially altered by the fact that many purchase decisions are made in the store.

Oxidation and Phosphorylation by Mitochondria from Green Stems

WU, LUNG-CHI AND R. P. SCHEFFER

Plant Physiology. 35(5): 708-713. 1960. (Journal Article 2592 from the Michigan Agricultural Experiment Station)

Particles isolated from green stems of tomato possessed the essential properties of mitochondria. Malate, succinate, fumarate, citrate, and a — ketoglutrate were oxidized, and the co-factors DPN, TPP, and CoA increased the rates of oxidation. Pyruvate served as a very poor substrate unless a catalytic amount of Kreb's cycle acid was added to the reaction mixture. Succinoxidase activity was

among the highest known for plant mitochondria. Phosphorylation depended on the addition of hexolinase to the reaction mixture, and P:O ratios from 2.3 to 3.2 were obtained with ketoglurate.

This work is basic to studies of biochemical changes with disease development.

Organic Acids in the Apple as Related to Variety and Source

KENWORTHY, A. L. AND NORMAN HARRIS

Food Tech. 14: 372-375. 1960 (Journal Article 2598 from the Michigan Agricultural Experiment Station)

Apple samples of the McIntosh, Golden Delicious, and Red Delicious varieties from a Michigan orchard and Golden Delicious from a Washington orchard were studied and analyzed for organic acids. Comparisons were made also on firmness, soluble solids content, percent dry matter, percent juice and CO_2 evolution.

Organic acid analyses of these samples were performed by means of paper chromatography of fractions collected from silica-gel columns. A total of 73 acids were used for identification. The detected acids had chromatographic properties similar to glyoxylic, isocitric, glutamic, malic, citric, m-tar-taric, oxalacetic, indole-3-acetic. Also, unidentified amino and uronic acids were found. The uronic acids were not galacturonic.

Results also indicated that varieties differ as to the amount and kind of organic acids present. The differences were believed to be due to genetic, climatic, and nutritional environments.

Free-Fat, Self-Dispersion and Flavor of Whole Milk Powder

REINKE, EUGENE, J. R. BRUNNER AND G. M. TROUT

Milk Prods. Jour. 51(9): 6-7, 24-25. 1960. (Journal Article 2606 from the Michigan Agricultural Experiment Station)

Variations in the processing of whole milk powder were followed. The small increase in free-fat encountered in these experiments was not reflected in poor dispersibility or flavor. Therefore, it may be concluded that processes conducive to increasing dispersibility and flavor stability are recommended and include (a) high heat treatment of fluid and/or condensed whole milk, (b) recombination of condensed skimmilk and cream or fresh butteroil, (c) mild treatment of condensed skimmilk with a proteolytic enzyme followed by recombination with cream or butteroil, (d) reduction of fat content of the powder to approximately 17-20%, and (e) employment of large orifice nozzles at relatively low nozzle pressures (i.e. ¼ SBC5 at 600 psi).

The Prediction of the Relative Yield of Different Oat Varieties Based on Known Environmental Variables

GRAFIUS, J. E. AND R. L. KIESLING

Agronomy Jour. 52: 366-399. 1960. (Journal Article 2642 from the Michigan Agricultural Experiment Station)

Vector technique was used to study the relative yield of 25 oat varieties grown under several environments. Five locations were found which represented

environmental stresses due to night temperature, drought, leaf and stem rust and lodging. These locations were used to construct orthogonal basis vectors from which nine other locations were predicted on the basis of the importance of each basis vector for that particular location.

The method can be used to predict relative yields of sets of varieties for areas in which no test is available. Also, long-time disease records and weather records can be used to give long-time performance predictions.

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